

LEVE #10  
VOLUME 13, NO. 12,  
DECEMBER 1981

A108290

AD A108290

# THE SHOCK AND VIBRATION DIGEST.

A PUBLICATION OF  
THE SHOCK AND VIBRATION  
INFORMATION CENTER  
NAVAL RESEARCH LABORATORY  
WASHINGTON, D.C.

DTIC  
ELECTED  
S JAN 13 1982  
D  
A

DTIC FILE COPY

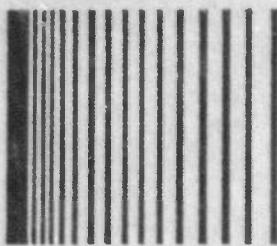


OFFICE OF  
THE UNDER  
SECRETARY  
OF DEFENSE  
FOR RESEARCH  
AND  
ENGINEERING

82 01 13 078

389004

Approved for public release; distribution unlimited.



# THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12  
December 1981

## STAFF

### SHOCK AND VIBRATION INFORMATION CENTER

EDITORIAL ADVISOR: Henry C. Pusey

### VIBRATION INSTITUTE

TECHNICAL EDITOR: Ronald L. Eshleman

EDITOR: Judith Nagle-Eshleman

RESEARCH EDITOR: Milda Z. Tamulionis

PRODUCTION: Deborah K. Howard  
Gwen Wassilak  
Vicki Pate



A publication of

THE SHOCK AND VIBRATION  
INFORMATION CENTER

Code 5804, Naval Research Laboratory  
Washington, D.C. 20375 3/100.60

No  
Copies

Henry C. Pusey  
Director

Rudolph H. Volin

J. Gordon Showalter

Jessica P. Hileman

Elizabeth A. McLaughlin

## BOARD OF EDITORS

R. Belsham	W.D. Pilkey
R.L. Bort	E. Sevin
J.D.C. Crisp	J.G. Showalter
D.J. Johns	R.A. Skop
K.E. McKee	R.H. Volin
C.T. Morrow	H.E. von Gierke

The Shock and Vibration Digest is a monthly publication of the Shock and Vibration Information Center. The goal of the Digest is to provide efficient transfer of sound, shock, and vibration technology among researchers and practicing engineers. Subjective and objective analyses of the literature are provided along with news and editorial material. News items and articles to be considered for publication should be submitted to:

Dr. R.L. Eshleman  
Vibration Institute  
Suite 206  
101 West 55th Street  
Clarendon Hills, Illinois 60514

Copies of articles abstracted are not available from the Shock and Vibration Information Center (except for those generated by SVIC). Inquiries should be directed to library resources, authors, or the original publishers.

This periodical is for sale on subscription at an annual rate of \$140.00. For foreign subscribers, there is an additional 25 percent charge for overseas delivery on both regular subscriptions and back issues. Subscriptions are accepted for the calendar year, beginning with the January issue. Back issues are available - Volumes 9 through 12 for \$15.00. Orders may be forwarded at any time to SVIC, Code 5804, Naval Research Laboratory, Washington, D.C. 20375. Issuance of this periodical is approved in accordance with the Department of the Navy Publications and Printing Regulations, NAVEXOS P-35.

# SVIC NOTES

## WHERE DID THAT NUMBER COME FROM?

Dynamic test requirements for equipment in vehicles often include numerical values and many users ask the question, "where did that number come from?" Interest in this subject is continuous but current efforts to revise MIL-STD-810, and requirements for test tailorability and for the disclosure of the rationale behind the numbers in test documents, have increased the awareness of this subject. Many methods have been used to set dynamic test requirements for vehicle equipment; it might be useful to briefly mention some of the more common of these.

First, if equipment is to be installed in an existing vehicle the establishment of test requirements might be simplified provided inputs from the vehicle to the item are available or can be measured.

If equipment is being developed for new vehicles it is only possible to establish preliminary test requirements at first because the equipment is usually developed before the vehicle exists. A typical orderly procedure includes the prediction of the expected dynamic environment followed by verification during field or laboratory tests once the prototype vehicle has become available. Many believe that preliminary test requirements should be slightly conservative to avoid the need to redesign the equipment and possible contractual difficulties if the operating environments turn out to be more severe than expected. Further details of this process have appeared in many of the previous Shock and Vibration Bulletins and papers on establishing qualification test requirements for airborne equipment will be published in the proceedings of the 53rd Meeting of the Advisory Group for Aerospace Research & Development (AGARD) Structures and Materials Panel which was recently held in the Netherlands.

Another method for setting dynamic test requirements for equipment in new vehicles is to use standards documents that contain guidelines that may be used to either derive test requirements or to establish the actual values of the dynamic test levels. Many prefer to use standards because they are convenient and often no other guidance is available. However, care must be taken in their use to avoid misinterpretation and this can only be done if the rationale behind the standard is known and understood. Many examples of the use of standards for establishing suitable dynamic test requirements for equipment in new vehicles are also available in the literature.

The foregoing are some of the more common methods for setting dynamic test requirements and other methods are available; some involve a combination of two or more of the methods that were previously mentioned, some are based on known physical limitations and still others are arbitrary. The most important requirements for any method for setting dynamic test requirements are that they must be as realistic as possible and that the rationale behind their numbers should be thoroughly documented.

R.H.V.

# EDITORS RATTLE SPACE

## DISTILLATION OF THE LITERATURE

Each year the twelfth issue of the DIGEST gives an indication of the volume of literature published in the shock and vibration area: there were almost 2700 abstracts published in the DIGEST in 1981. This represents a 40 percent increase in publications since 1978. At this rate of growth one wonders when the publishing system will go unstable and self destruct!

The increasing number of abstracts means that more and more information is being written in the shock and vibration field. More technology is thus available to the engineer trying to solve problems. Unfortunately, more is not always better. The large volume of literature means that the engineer will have to use valuable time attempting to identify pertinent articles and information. It is true that the abstract of an article or report can be retrieved as part of a subject or problem area, but this is only the beginning of the process of identifying what literature may be helpful in solving a problem or advancing a research and development project. The articles must be studied and analyzed to determine the available pertinent information. As the volume of literature increases, so does the time required to distill it. This brings us to the point of this editorial: the effort expended on literature reviews and distillation should increase in proportion to the growing volume of literature.

In past years the literature was distilled in textbooks and specialized technical books. This was and is a slow process. Today the distillation of the literature in book form is not keeping up with the growing volume of literature. The literature review section of the DIGEST is devoted to distillation of the literature – and is meant to provide an objective analysis of the literature. Many literature review articles are published in the DIGEST and in other journals, but other specific technical areas should also be reviewed. I feel that more effort should go into the writing of review articles. If you are interested in writing a review article, please contact the editors of the DIGEST.

R.L.E.

SEARCHED	INDEXED
SERIALIZED	FILED
APR 10 1980	
FIRESHOCK & VIBRATION DIGEST	
AVAILABILITY DATA	
A 21	

## FINITE-ELEMENT MODELING OF LAYERED, ANISOTROPIC COMPOSITE PLATES AND SHELLS: A REVIEW OF RECENT RESEARCH

J.N. Reddy\*

*Abstract. This paper reviews finite element papers published in the open literature on the static bending and free vibration of layered, anisotropic, and composite plates and shells. The paper also contains a literature review of large-deflection bending and large-amplitude free oscillations of layered composite plates and shells. Non-finite element literature is also cited for continuity of the discussion.*

In recent years composites, especially fiber-reinforced laminates, have found increasing application in many engineering structures. This is mainly due to two desirable features of fiber-reinforced composites: a high stiffness-to-weight ratio and the anisotropic material property that can be tailored through variation of the fiber orientation and stacking sequence of lamina - a feature that gives the designer flexibility. The increased use of fiber-reinforced composites as structural elements has generated considerable interest in the analysis of laminated (anisotropic) composite plates and shells.

Recent developments in the analysis of plates and shells laminated of fiber-reinforced materials indicate that thickness has a more pronounced effect on the behavior of composite laminates than on isotropic laminates. Classical thin-plate and thin-shell theories assume that normals to the midsurface before deformation remain straight and normal to the midsurface after deformation; the implication is that thickness shear deformation effects are negligible. As a result, natural frequencies calculated using the thin-plate theory are higher than those obtained by including transverse shear deformation effects. In addition, the transverse deflections predicted by thin-plate theory are lower than those predicted by shear deformable theory (SDT). Due to the low transverse shear modulus relative to the in-plane Young's moduli, transverse shear deformation effects are even

more pronounced in composite laminates. Reliable prediction of the small deflection response characteristics of high modulus composite plates and shells therefore requires the use of shear deformable theories.

When the transverse deflections experienced by plates and shells are not small compared to laminate thickness, the interaction between membrane stresses and the curvatures - bending and shear - of the laminate must be considered. The interaction results in midplane stretching, which leads to nonlinear terms in the equations of motion. Thus, a more accurate prediction of deflections, stresses, and frequencies requires a solution of the laminate equations that can account for large deflections and thickness shear deformation.

### LITERATURE REVIEW OF PLATES

**Small-deflection theory of plates.** A number of shear deformable theories for laminated plates have been proposed to date. The first theory for laminated isotropic plates is that of Stavsky [1]. The theory has been generalized to laminated anisotropic plates by Yang, Norris, and Stavsky [2]. Their work, called the Yang-Norris-Stavsky (YNS) theory, represents a generalization of Reissner-Mindlin plate theory for homogeneous isotropic plates to arbitrarily laminated anisotropic plates and includes shear deformation and rotatory inertia effects. A review of other theories, for example, the effective stiffness theory of Sun and Whitney [3], the higher-order theory of Whitney and Sun [4], and the three-dimensional elasticity theory of Srinivas et al [5-7], has been reviewed in [8]. It has been shown [3, 5, 9-13] that the YNS theory is adequate for predicting such overall behavior as transverse deflections and natural frequencies (first few modes) of laminated anisotropic plates.

\*Professor, Department of Engineering Science and Mechanics, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061

The first application of the YNS theory is apparently due to Whitney and Pagano [14], who presented closed-form solutions for symmetric and antisymmetric cross-ply and angle-ply rectangular plates under sinusoidal load distribution and for free vibration of antisymmetric angle-ply rectangular plates. Fortier and Rosettos [15] analyzed the free vibration of thick rectangular plates of unsymmetric cross-ply construction; Sinha and Rath [16] considered both vibration and buckling for the same type of plates. Following Whitney and Pagano [14], Bert and Chen [17] presented a closed-form solution for the free vibration of simply supported rectangular plates of antisymmetric angle-ply laminates.

Finite-element analysis of layered composite plates began with Pryor and Barker [18] and Barker, Lin, and Dana [19], who employed an element with seven degrees of freedom (three displacements, two rotations, and two shear slopes) per node to analyze thick laminated plates. Mau, Tong, and Pian [20] and Mau, Pian, and Tong [21] used the so-called hybrid-stress finite-element method to analyze thick composite plates. Noor and Mathers [22, 24] used finite element models based on a form of Reissner's plate theory -- i.e., mixed formulation -- to study the effects of shear deformation and anisotropy on the response of laminated anisotropic plates. One of the elements used had 80 degrees of freedom per element and thus required enormous computational resources. Hinton [24] used the so-called finite strip method to study the free vibration of layered cross-ply laminated plates. Mawenya and Davies [26] and Panda and Natarajan [27] used the quadratic shell element of Ahmad, Irons, and Zienkiewicz [28] to analyze the bending of thick multi-layer plates. Spilker, Chou, and Orringer [29] used two hybrid-stress elements to study the static bending of layered composite plates. The number of degrees of freedom in one of the two elements is proportional to the number of layers; therefore, the core storage and execution time requirements for the element increase rapidly with the number of layers in the plate. Reddy [30] recently developed a simple and efficient finite element based on the YNS theory. The element contains three displacements and two bending slopes as degrees of freedom per node. The accuracy and convergence characteristics of the element have been investigated [31]. The element has been used successfully in the free vibration and

thermoelastic analysis of ordinary and bimodulus (i.e., different elastic properties in tension and compression) layered composite plates [30-34].

**Large-deflection theory of plates.** Much of the research in the analysis of composite plates is limited to linear problems. This is perhaps due to the complexity of the nonlinear partial differential equation associated with the large-deflection theory of composite plates. Approximate solutions to the large-deflection theory (in the von Karman sense) of laminated composite plates have been attempted [35-43]. Chandra and Raju [38, 39] and Chia and Prabhakara [41, 42] employed the Galerkin method to reduce the governing nonlinear partial differential equations to an ordinary differential equation in time for the mode shape; the perturbation technique was used to solve the resulting equation. Zaghloul and Kennedy [40] used a finite-difference successive iterative technique in their analysis. In all of these studies with one exception [43], the transverse shear effects were neglected. The finite element employed by Noor and Hartley [43] includes the effect of transverse shear strains; however, it is algebraically complex and involves a large number of degrees of freedom per element. The use of such elements can thus be precluded in the nonlinear analysis of composite plates. Reddy and Chao [44, 45] recently adapted a shear deformable finite element [30] to the nonlinear bending of composite plates.

Analysis of nonlinear vibration of single-layer orthotropic plates has been done [46, 47]. Nowinski [48, 49] analyzed rectilinearly orthotropic plates of circular and triangular planforms using the Galerkin method; the effects of transverse shear deformation and rotatory inertia were not considered. Wu and Vinson [50] presented the dynamic analogue of Berger's equation of motion for an orthotropic plate, including the effect of transverse shear deformation and rotatory inertia; however, the solutions were restricted to transverse shear deformation. Mayberry and Bert [51] presented experimental as well as theoretical work on nonlinear vibration of laminated plates; the theoretical investigation was limited to a single-layer specially orthotropic rectangular plate with all four edges clamped and did not include the effect of transverse shear deformation and rotatory inertia. Nowinski [52] and others [53] used an assumed mode shape and Galerkin method to present a general equation for the nonlinear

analysis (i.e., large deflection and large amplitude free vibration) of orthotropic plates. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear vibration of a rectangular orthotropic plate with all simply supported and all clamped edges. The effect of transverse shear and rotatory inertia on large amplitude vibration of composite plates was reported recently by Sathyamoorthy and Chia [55-57]. They used the Galerkin method and the Runge-Kutta numerical procedure.

In general, layered composite plates exhibit coupling between the in-plane displacements and the transverse displacement and shear rotations. For plates having layers stacked symmetrically with respect to the midplane, the bending-stretching coupling terms vanish and the problem is relatively simpler. Wu and Vinson [58] extended their earlier work [50] to deal with the nonlinear vibration of symmetrically stacked laminated composite plates. The first nonlinear vibration analysis of unsymmetrically laminated plates is that of Bennett [36], who considered simply supported (with immovable edges) angle-ply plates. Bert [37] used the thin plate theory of layered composite plates and the Galerkin method to investigate the nonlinear vibration of a rectangular plate arbitrarily laminated of anisotropic material. A multimode (two-term) solution for nonlinear vibration of unsymmetric all-clamped and all-simply supported angle-ply and cross-ply laminated plates was reported by Chandra and Basava Raju [38, 39, 59]. Chandra [39] used a one-term Galerkin approximation for the dynamic von Karman plate equations and the perturbation technique for the resulting ordinary equation in time to investigate the large-amplitude vibration of a cross-ply plate that is simply supported at two opposite edges and clamped at the other two edges. Prabhakara and Chia [54] presented an analytical investigation of the nonlinear free flexural vibrations of unsymmetric cross-ply and angle-ply plates with all-clamped and all-simply supported edges. The normal and tangential boundary forces in the plane of the plate were assumed to be zero. Reddy [60, 61] and Reddy and Chao [62] recently investigated the large-amplitude free vibration of layered composite plates using the finite-element method; they considered transverse shear and rotatory inertia effects. The finite-element studies [60, 62] are apparently the first to consider the nonlinear vibrations of layered anisotropic composite plates including transverse shear deformation.

Additional references, especially those before 1980, can be found in survey articles [63-67].

## LITERATURE REVIEW OF SHELLS

**Small-deflection theory of shells.** The first analysis that incorporated the bending-stretching coupling (due to unsymmetric lamination) in shells is that of Ambartsumyan [68, 69]. He assumed that the individual orthotropic layers were oriented so that the principal axes of material symmetry coincided with the principal coordinates of the shell reference surface. Thus, Ambartsumyan's work dealt with what is now known as laminated orthotropic shells rather than with laminated anisotropic shells. In laminated anisotropic shells the individual layers are generally anisotropic; in addition, the principal axes of material symmetry of the individual layers do not coincide with the principal coordinates of the shell.

In 1962 Dong, Pister, and Taylor [70] formulated a theory of thin shells laminated of anisotropic material. The theory is an extension of that developed by Stavsky [71] for laminated anisotropic plates to Donnell's shallow shell theory [78] of shells. Cheng and Ho [73] analyzed laminated anisotropic cylindrical shells using Flügge's shell theory [74]. Bert [75] combined Vlasov's shell theory [76] with the most general anisotropic constitutive equations of Stavsky [71] to obtain an arbitrary shell geometry. A first-approximation theory for the unsymmetric deformation of nonhomogeneous, anisotropic, elastic cylindrical shells was derived by Widera and Chung [77]; they used the asymptotic integration of the elasticity equations. For a homogeneous, isotropic material the theory reduces to the Donnell equations [78]. An exposition of various shell theories is available [79].

All of the theories discussed above are based on Kirchhoff-Love's hypotheses [72], in which transverse shear deformation is neglected. The effect of transverse shear deformation and transverse isotropy, as well as thermal expansion through the shell thickness have been considered by Zukas and Vinson [80] and Dong and Tso [81]. The theory used by Dong and Tso [81] is applicable only to layered, orthotropic, cylindrical shells; i.e., the orthotropic axes of each layer coincide with the coordinate axes of the shell. Whitney and Sun [82] developed a shear deformable

theory for laminated cylindrical shells that includes transverse shear deformation and transverse normal strain as well as expansional strains. Widera and Logan [83, 84] recently presented refined theories for nonhomogeneous anisotropic cylindrical shells.

As far as the finite-element analysis of shells is concerned, layered composite shells have not received the attention given to ordinary shells. The works of Dong [85] on statically-loaded orthotropic shell of revolution, Dong and Selna [86] on free vibration of the same, Wilson and Parsons [87] on static axisymmetric loading of arbitrarily thick orthotropic shells of revolution, and Schmit and Monforton [88] on laminated anisotropic cylindrical shells are the only ones that considered the finite-element method before 1970. The last reference is the only one that considered laminated anisotropic shells. During the 1970s there was increased interest in the finite-element analysis of bending and vibration of laminated anisotropic shells. A finite-element application in laminated anisotropic shells of arbitrary geometry is due to Thompson [89], who presented free vibration of general laminated anisotropic thin shells. Other finite-element analyses of layered anisotropic composite shells are available [90-100]; the effect of shear deformation was included in two papers [93, 100].

**Large-deflection theory of shells.** Despite the importance of nonlinear analyses of layered anisotropic shells, there is apparently no literature on the subject with the exception of the mixed finite-element analysis of Noor and Hartley [101] and recent work by Chang and Sawamiphakdi [102] and Reddy [103]. The work [102] utilizes a degenerated three-dimensional isoparametric element based on an updated Lagrangian description. In [103] a shear flexible finite element was developed based on a shell theory that combines various first-approximation shell theories [72, 78, 104-106]. The theory also accounts for large rotations.

### CONCLUDING REMARKS

The bending and vibration analysis of layered anisotropic composite plates and shells is more complicated – due to bending-stretching coupling – than is the classical, isotropic, homogeneous analysis of

plates and shells. Because of these complexities, the available literature is sparse, especially in the area of nonlinear analysis of shells, compared to that of ordinary plates and shells.

Although the first-order shear deformable theories of layered composite plates yield acceptable solutions for global response of plates and shells, the theories do not accurately predict stress singularities and higher-order frequencies. The questions relating to interlaminar stresses, edge effects, and delamination in composites [107-116] can be addressed only when higher-order, three-dimensional theories are employed [82, 117-120].

As the use of composites for high performance design applications increases, the need for more realistic theoretical and experimental prediction of the response characteristics of composite-material structures will become increasingly important.

### ACKNOWLEDGMENT

Support of this work by the Structural Mechanics Program of the Air Force Office of Scientific Research (Grant AFOSR-81-0142) and the Structures Research Section of the NASA (Lewis Grant NAG. 3-208) is gratefully acknowledged.

### REFERENCES

1. Stavsky, Y., "On the Theory of Symmetrically Heterogeneous Plates Having the Same Thickness Variation of the Elastic Moduli," Topics in Applied Mechanics, (Abir, D., Ollendorff, F., and Reiner, M., Eds.), American Elsevier (1965).
2. Yang, P.C., Norris, C.H., and Stavsky, Y., "Elastic Wave Propagation in Heterogeneous Plates," Intl. J. Solids Struct., 2, pp 665-684 (1966).
3. Sun, C.T. and Whitney, J.M., "Theories for the Dynamic Response of Laminated Plates," AIAA J., 11, pp 178-183 (1973).
4. Whitney, J.M. and Sun, C.T., "A Higher Order Theory for Extensional Motion of Laminated Composites," J. Sound Vib., 30, pp 85-97 (1973).

5. Srinivas, S. and Rao, A.K., "Bending, Vibration and Buckling of Simply Supported Thick Orthotropic Rectangular Plates and Laminates," *Intl. J. Solids Struc.*, 6, pp 1463-1481 (1970).
6. Srinivas, S., Joga Rao, C.V., and Rao, A.K., "An Exact Analysis for Vibration of Simply Supported Homogeneous and Laminated Thick Rectangular Plates," *J. Sound Vib.*, 12, pp 187-199 (1970).
7. Hussainy, S.A. and Srinivas, S., "Flexure of Rectangular Composite Plates," *Fibre Sci. Tech.*, 8, pp 59-76 (1975).
8. Bert, C.W., "Analysis of Plates," Structural Design and Analysis, Part I (Chamis, C.C., Ed.), Academic Press, (1974).
9. Pagano, N.J., "Exact Solutions for Composite Laminates in Cylindrical Bending," *J. Composite Matls.*, 3 (3), pp 398-411 (1969).
10. Pagano, N.J., "Exact Solutions for Rectangular Bidirectional Composites and Sandwich Plates," *J. Composite Matls.*, 4, pp 20-34 (1970).
11. Pagano, N.J. and Hatfield, S.J., "Elastic Behavior of Multilayer Bidirectional Composites," *AIAA J.*, 10, pp 931-933 (1972).
12. Whitney, J.M., "The Effect of Transverse Shear Deformation on the Bending of Laminated Plates," *J. Composite Matls.*, 3 (3), pp 534-547 (1969).
13. Mau, S.T., "A Refined Laminated Plate Theory," *J. Appl. Mechanics, Trans. ASME*, 40, pp 606-607 (1973).
14. Whitney, J.M. and Pagano, N.J., "Shear Deformation in Heterogeneous Anisotropic Plates," *J. Appl. Mechanics, Trans. ASME*, 37, pp 1031-1036 (1970).
15. Fortier, R.C. and Rossettos, J.N., "On the Vibration of Shear Deformable Curved Anisotropic Composite Plates," *J. Appl. Mech., Trans. ASME*, 40, pp 299-301 (1973).
16. Sinha, P.K. and Rath, A.K., "Vibration and Buckling of Cross-Ply Laminated Circular Cylindrical Panels," *Aeronaut. Quart.*, 26, pp 211-218 (1975).
17. Bert, C.W. and Chen, T.L.C., "Effect of Shear Deformation on Vibration of Antisymmetric Angle-Ply Laminated Rectangular Plates," *Intl. J. Solids Struc.*, 14, pp 465-473 (1978).
18. Pryor, C.W., Jr. and Barker, R.M., "A Finite Element Analysis Including Transverse Shear Effects for Applications to Laminated Plates," *AIAA J.*, 9, pp 912-917 (1971).
19. Barker, R.M., Lin, F.T., and Dana, J.R., "Three Dimensional Finite-Element Analysis of Laminated Composites," *Natl. Symp. Computerized Structural Anal. Des.*, George Washington Univ. (1972).
20. Mau, S.T., Tong, P., and Pian, T.H.H., "Finite Element Solutions for Laminated Thick Plates," *J. Composite Matls.*, 6, pp 304-311 (1972).
21. Mau, S.T., Pian, T.H.H., and Tong, P., "Vibration Analysis of Laminated Plates and Shells by a Hybrid Stress Element," *AIAA J.*, 11, pp 1450-1452 (1973).
22. Noor, A.K., "Free Vibrations of Multilayered Composite Plates," *AIAA J.*, 11, pp 1038-1039 (1973).
23. Noor, A.K. and Mathers, M.D., "Anisotropy and Shear Deformation in Laminated Composite Plates," *AIAA J.*, 14, pp 282-285 (1976).
24. Noor, A.K. and Mathers, M.D., "Finite Element Analysis of Anisotropic Plates," *Intl. J. Numer. Methods Engr.*, 11, pp 289-307 (1977).
25. Hinton, E., "A Note on a Thick Finite Strip Method for the Free Vibration of Laminated Plates," *Intl. J. Earthquake Engr. Struct. Dynam.*, 4, pp 511-514 (1976).
26. Mawenya, A.S. and Davies, J.D., "Finite Element Bending Analysis of Multilayer Plates," *Intl. J. Numer. Methods Engr.*, 8, pp 215-225 (1974).

27. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Composite Plates," *Intl. J. Numer. Methods Engr.*, 14, pp 69-79 (1979).

28. Ahmad, S., Irons, B.M., and Zienkiewicz, O.C., "Analysis of Thick and Thin Shell Structures by Curved Finite Elements," *Intl. J. Numer. Methods Engr.*, 2, pp 419-451 (1970).

29. Spilker, R.L., Chou, S.C., and Orringer, O., "Alternate Hybrid Stress Elements for Analysis of Multilayer Composite Plates," *J. Composite Matls.*, 11, pp 51-70 (1977).

30. Reddy, J.N., "A Penalty Plate-Bending Element for the Analysis of Laminated Anisotropic Composite Plates," *Intl. J. Numer. Methods Engr.*, 15, pp 1187-1206 (1980).

31. Reddy, J.N. and Chao, W.C., "A Comparison of Closed-Form and Finite Element Solutions of Thick Laminated Anisotropic Rectangular Plates," *Nuclear Engr. Des.*, 64 (1981).

32. Reddy, J.N., "Free Vibration of Antisymmetric, Angle-Ply Laminated Plates, Including Transverse Shear Deformation by the Finite Element Method," *J. Sound Vib.*, 66 (4), pp 565-576 (1979).

33. Reddy, J.N. and Bert, C.W., "Analyses of Plates Constructed of Fiber-Reinforced Bimodulus Materials," *Mechanics of Bimodulus Materials*, (Bert, C.W., Ed.), AMD Vol. 33, ASME, pp 29-37 (1979).

34. Reddy, J.N. and Chao, W.C., "Finite-element Analysis of Laminated Bimodulus Composite-Material Plates," *Computers Struc.*, 12, pp 245-251 (1980).

35. Whitney, J.M. and Leissa, A.W., "Analysis of Heterogeneous Anisotropic Plates," *J. Appl. Mechanics, Trans. ASME*, 36, pp 261-266 (1969).

36. Bennett, J.A., "Nonlinear Vibration of Simply Supported Angle Ply Laminated Plates," *AIAA J.*, 9, pp 1997-2003 (1971).

37. Bert, C.W., "Nonlinear Vibration of a Rectangular Plate Arbitrarily Laminated of Anisotropic Material," *J. Appl. Mechanics, Trans. ASME*, 40, pp 452-458 (1973).

38. Chandra, R. and Raju, B.B., "Large Amplitude Flexural Vibration of Cross-Ply Laminated Composite Plates," *Fibre Sci. Tech.*, 8, pp 243-263 (1975).

39. Chandra, R., "Large Deflection Vibration of Cross-Ply Laminated Plates with Certain Edge Conditions," *J. Sound Vib.*, 47 (4), pp 509-514 (1976).

40. Zaghloul, S.A. and Kennedy, J.B., "Nonlinear Analysis of Unsymmetrically Laminated Plates," *ASCE J. Engr. Mechanics Div.*, 101 (EM3), pp 169-185 (1975).

41. Chia, C.Y. and Prabhakara, M.K., "Large Deflection of Unsymmetric Cross-Ply and Angle-Ply Plates," *J. Mech. Engr. Sci.*, 18 (4), pp 179-183 (1976).

42. Chia, C.Y. and Prabhakara, M.K., "A General Mode Approach to Nonlinear Flexural Vibrations of Laminated Rectangular Plates," *J. Appl. Mechanics, Trans. ASME*, 45, pp 623-628 (1978).

43. Noor, A.K. and Hartley, S.J., "Effect of Shear Deformation and Anisotropy on the Non-Linear Response of Composite Plates," *Developments in Composite Materials - 1*, (Holister, G., Ed.), *Appl. Sci. Publ.*, Barking, Essex, England, pp 55-65 (1977).

44. Reddy, J.N. and Chao, W.C., "Large Deflection and Large Amplitude Free Vibrations of Laminated Composite Material Plates," *Computers Struc.*, 13 (2), pp 341-347 (1981).

45. Reddy, J.N. and Chao, W.C., "Non-Linear Bending of Thick Rectangular, Laminated Composite Plates," *Intl. J. Nonlin. Mechanics* (1981).

46. Ambartsumyan, S.A., *Theory of Anisotropic Plates* (English Translation), Technomic, Stamford, CT (1970).

47. Hassert, J.E. and Nowinski, J.L., "Nonlinear Transverse Vibration of a Flat Rectangular Orthotropic Plate Supported by Stiff Rig," Proc. 5th Intl. Symp. Space Tech. Sci., Tokyo, pp 561-570 (1962).

48. Nowinski, J.L., "Nonlinear Vibrations of Elastic Circular Plates Exhibiting Rectilinear Orthotropy, Z. Angew Meth. Physik, 14, pp 112-124 (1963).

49. Nowinski, J.L. and Ismail, I.A., "Large Oscillations of an Anisotropic Triangular Plate," J. Franklin Inst., 280, pp 417-424 (1965).

50. Wu, C.I. and Vinson, J.R., "On the Nonlinear Oscillations of Plates Composed of Composite Materials," J. Composite Matls., 3, pp 548-561 (1969).

51. Mayberry, B.L. and Bert, C.W., "Experimental Investigation of Nonlinear Vibrations of Laminated Anisotropic Panels, Shock Vib. Bull., U.S. Naval Res. Lab., Proc. 39, Pt 3, pp 191-199 (1969).

52. Nowinski, J.L., "Nonlinear Oscillations of Anisotropic Plates under Large Initial Stress," Proc. 10th Cong. Theoret. Appl. Mechanics, Madras, India, pp 13-30 (1965).

53. Sathyamoorthy, M. and Pandalai, K.A., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Aeronaut. Soc. India, 22, pp 264-266 (1970).

54. Prabhakara, M.K. and Chia, C.Y., "Nonlinear Flexural Vibrations of Orthotropic Rectangular Plates," J. Sound Vib., 52, pp 511-518 (1977).

55. Sathyamoorthy, M. and Chia, C.Y., "Non-Linear Vibration of Anisotropic Rectangular Plates Including Shear and Rotatory Inertia," Fibre Sci. Tech., 13, pp 337-361 (1980).

56. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 1: Theory," J. Appl. Mechanics, Trans. ASME, 47, pp 128-132 (1980).

57. Sathyamoorthy, M. and Chia, C.Y., "Effect of Transverse Shear and Rotatory Inertia on Large Amplitude Vibration of Anisotropic Skew Plates; Part 2: Numerical Results," J. Appl. Mechanics, Trans. ASME, 47, pp 133-138 (1980).

58. Wu, C.I. and Vinson, J.R., "Nonlinear Oscillations of Laminated Specially Orthotropic Plates with Clamped and Simply Supported Edges," J. Acoust. Soc. Amer., 49, pp 1561-1567 (1971).

59. Chandra, R. and Basava Raju, B., "Large Deflection Vibration of Angle Ply Laminated Plates," J. Sound Vib., 40, pp 393-408 (1975).

60. Reddy, J.N., "Nonlinear Vibration of Layered Composite Plates Including Transverse Shear and Rotatory Inertia," 1981 ASME Vib. Conf., Hartford, CT (Sept 20-23, 1981).

61. Reddy, J.N., "Analysis of Layered Composite Plates Accounting for Large Deflections and Transverse Shear Strains," Recent Advances in Nonlinear Computational Mechanics (E. Hinton et al., Eds.), Pineridge Press, Swansea, United Kingdom (to appear).

62. Reddy, J.N. and Chao, W.C., "Nonlinear Oscillations of Laminated Anisotropic, Thick, Rectangular Plates," Struc. Matls. Conf., 1981 Winter Ann. Mtg. ASME, Washington, DC.

63. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part I, Shock Vib. Dig., 8 (10), pp 37-48 (Oct 1976).

64. Bert, C.W., "Dynamics of Composite and Sandwich Panels," Part II, Shock Vib. Dig., 8 (11), pp 15-24 (Nov 1976).

65. Bert, C.W., "Vibration of Composite Structures," Proc. Intl. Conf. Recent Advances Struc. Dynam., Univ. of Southampton, Southampton, England (July 7-11, 1980).

66. Reddy, J.N., "Finite Element Modeling of Structural Vibrations: A Review of Recent Advances," Shock Vib. Dig., 11 (1), pp 25-39 (Jan 1979).

67. Leissa, A.W., "Advances in Vibration, Buckling and Postbuckling Studies on Composite Plates," *Intl. Conf. Composite Struc.*, Paisley, Scotland (Sept 16-18, 1981).

68. Ambartsumyan, S.A., "Calculation of Laminated Anisotropic Shells," *Izvestia Akademii Nauk Armenskoi SSR, Ser. Fiz. Mat. Est. Tekh. Nauk.*, 6 (3), p 15 (1953).

69. Ambartsumyan, S.A., *Theory of Anisotropic Shells*. Moscow, 1961; English translation, NASA TT F-118 (May 1964).

70. Dong, S.B., Pister, K.S., and Taylor, R.L., "On the Theory of Laminated Anisotropic Shells and Plates," *J. Aerospace Sci.*, 29, pp 969-975 (1962).

71. Stavsky, Y., "Bending and Stretching of Laminated Anisotropic Plates," *ASCE J. Engr. Mechanics Div.*, 87 (EM6), p 31 (1961).

72. Love, A.E.H., "On the Small Free Vibrations and Deformations of the Elastic Shells," *Philosoph. Trans. Royal Soc. (London)*, Ser. A, 17, pp 491-546 (1888).

73. Cheng, S. and Ho, B.P.C., "Stability of Heterogeneous Aeolotropic Cylindrical Shells under Combined Loading," *J. Amer. Inst. Aeronaut. Astronaut.*, 1 (4), pp 892-898 (1963).

74. Flugge, W., Stresses in Shells, Springer-Verlag, Berlin (1960).

75. Bert, C.W., "Structural Theory for Laminated Anisotropic Elastic Shells," *J. Composite Matis.*, 1, pp 414-423 (1967).

76. Vlasov, V.Z., General Theory of Shells and Its Applications in Engineering, Moscow, 1949; English Translation, NASA TT F-99 (1964).

77. Widera, O.E. and Chung, S.W., "A Theory for Non-Homogeneous Anisotropic Cylindrical Shells," *Z. Angew Math. Physik*, 21, pp 378-399 (1970).

78. Donnell, L.H., "Stability of Thin Walled Tubes in Torsion," *NACA Rep.* 479 (1933).

79. Bert, C.W., "Analysis of Shells," Analysis of Performance of Composites, (Broutman, L.G., Ed.), Wiley, NY, Ch. 5, pp 207-258 (1980).

80. Zukas, J.A. and Vinson, J.R., "Laminated Transversely Isotropic Cylindrical Shells," *J. Appl. Mechanics, Trans. ASME*, pp 400-407 (1971).

81. Dong, S.B. and Tso, F.K.W., "On a Laminated Orthotropic Shell Theory Including Transverse Shear Deformation," *J. Appl. Mechanics, Trans. ASME*, 39, pp 1091-1097 (1972).

82. Whitney, J.M. and Sun, C.T., "A Refined Theory for Laminated Anisotropic, Cylindrical Shells," *J. Appl. Mechanics*, 41, pp 471-476 (1974).

83. Widera, G.E.O. and Logan, D.L., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part I: Derivation," *ASCE J. Engr. Mechanics Div.*, 106 (EM6), pp 1053-1074 (1980).

84. Logan, D.L. and Widera, G.E.O., "Refined Theories for Nonhomogeneous Anisotropic Cylindrical Shells; Part II: Application," *ASCE J. Engr. Mechanics Div.*, 106 (EM6), pp 1075-1090 (1980).

85. Dong, S.B., "Analysis of Laminated Shells of Revolution," *ASCE J. Engr. Mechanics Div.*, 92 (EM6), p 135 (1966).

86. Dong, S.B. and Selna, L.G., "Natural Vibrations of Laminated Orthotropic Shells of Revolution," *J. Composite Matis.*, 4 (1), pp 2-19 (1970).

87. Wilson, E.A. and Parsons, B., "The Finite Element Analysis of Filament-Reinforced Axisymmetric Bodies," *Fibre Sci. Tech.*, 2, pp 155-156 (1969).

88. Schmit, L.A. and Monforton, G.R., "Finite Element Analysis of Sandwich Plate and Laminate Shells with Laminated Faces," *J. Amer. Inst. Aeronaut. Astronaut.*, 8, pp 1454-1461 (1970).

89. Thompson, G.L., "Finite-Element Analysis for Free Vibration of General Anisotropic Laminated Thin Shells," Composite Materials in Engineering Design (Proc. 6th St. Louis Symp., May 1972), (Noton, B.R., Ed.), ASM (1973).

90. Padavan, J., "Quasi-Analytical Finite Element Procedures for Axisymmetric Anisotropic Shells and Solids," Computers Struc., 4, pp 467-483 (1974).

91. Padavan, J., "Numerical Analysis of Asymmetric Frequency and Buckling Eigenvalues of Prestressed Rotating Anisotropic Shells of Revolution," Computers Struc., 5, pp 145-154 (1975).

92. Padavan, J., "Travelling Waves Vibrations and Buckling of Rotating Anisotropic Shells of Revolution by Finite Elements," Intl. J. Solids Struc., 11, pp 1367-1380 (1975).

93. Noor, A.K. and Mathers, M.D., "Shear-Flexible Finite-Element Models of Laminated Composite Plates and Shells," NASA TN D-8044, Langley Res. Ctr., Hampton, VA.

94. Noor, A.K. and Camin, R.A., "Symmetry Considerations for Anisotropic Shells," Computer Methods Appl. Mechanics Engr., 9, pp 317-335 (1976).

95. Noor, A.K. and Andersen, C.M., "Mixed Isoparametric Finite Element Models of Laminated Composite Shells," Computer Methods Appl. Mechanics Engr., 11 (3), pp 255-280 (1977).

96. Panda, S.C. and Natarajan, R., "Finite Element Analysis of Laminated Shells of Revolution," Computers Struc., 6, pp 61-64 (1976).

97. Shivakumar, K.N. and Krishna Murty, A.V., "A High Precision Ring Element for Vibrations of Laminated Shells," J. Sound Vib., 58 (3), pp 311-318 (1978).

98. Rao, K.P., "A Rectangular Laminated Anisotropic Shallow Thin Shell Finite Element," Computer Methods Appl. Mechanics Engr., 15, pp 13-33 (1978).

99. Siede, P. and Chang, P.H.H., "Finite Element Analysis of Laminated Plates and Shells," NASA CR-157106 (1978).

100. Hsu, Y.S., Reddy, J.N., and Bert, C.W., "Thermoelasticity of Circular Cylindrical Shells Laminated of Bimodulus Composite Materials," J. Thermal Stresses, 4 (2) (1981).

101. Noor, A.K. and Hartley, S.J., "Nonlinear Shell Analysis via Mixed Isoparametric Elements," Computers Struc., 7, pp 615-626 (1977).

102. Chang, T.Y. and Sawamiphakdi, K., "Large Deformation Analysis of Laminated Shells by Finite Element Method," Computers Struc., 13, pp 331-340 (1981).

103. Reddy, J.N., "A Finite-Element Analysis of Large-Deflection Bending of Laminated Anisotropic Shells," Symp. Nonlin. Finite-Element Analysis Shells, 1981 Winter Ann. Mtg. ASME, Washington, DC (Nov 15-20, 1981).

104. Sanders, J.L., Jr., "An Improved First Approximation Theory for Thin Shells," NASA TR R-24 (June 1959).

105. Loo, T.T., "An Extension of Donnell's Equation for a Circular Cylindrical Shell," J. Aerospace Sci., 24, pp 390-391 (1957).

106. Morley, L.S.D., "An Improvement of Donnell's Approximation of Thin-Walled Circular Cylinders," Quart. J. Mech. Appl. Math., 8, pp 87-99 (1959).

107. Hayashi, T., "Analytical Study of Interlaminar Shear Stresses in a Laminated Composite Plate," Trans. Japan Soc. Aero. Engr. Space Sci., 10 (47), p 43 (1967).

108. Pagano, N.J., "Stress Fields in Composite Laminates," Intl. J. Solids Struc., 14, pp 385-400 (1978).

109. Pagano, N.J., "Free Edge Stress Fields in Composite Laminates," Intl. J. Solids Struc., 14, pp 401-406 (1978).

110. Wang, A.S.D. and Crossman, F.W., "Some New Results on Edge Effect in Symmetric

Composite Laminates, *J. Composite Matls.*, 8, pp 92-106 (1977).

111. Salamon, N.J., "Interlaminar Stresses in a Layered Composite Laminate in Bending," *Fibre Sci. Tech.*, 11, pp 305-317 (1978).

112. Wang, S.S. and Choi, I., "Boundary Layer Thermal Stresses in Angle-Ply Composite Laminates," *Modern Developments in Composite Materials and Structures*, (Vinson, J.R., Ed.), ASME, pp 315-341 (1979).

113. Wang, S.S., "Edge Delamination in Angle-Ply Composite Laminates," *Proc. 22nd AIAA/ASME/SAE Struc., Struc. Dynam., Matls. Conf.*, Atlanta, GA, pp 473-484 (1981).

114. Spilker, R.L. and Chou, S.C., "Edge Effects in Symmetric Composite Laminates: Importance of Satisfying the Traction-Free-Edge Condition," *J. Composite Matls.*, 14, pp 2-20 (1980).

115. Raju, I.S. and Crews, J.H., Jr., "Interlaminar Stress Singularities at a Straight Free Edge in Composite Laminates," *NASA Tech. Memo.* 81876, Langley Res. Ctr., Hampton, VA (1980).

116. Raju, I.S., Whitcomb, J.D., and Goree, J.G., "A New Look at Numerical Analysis of Free-Edge Stresses in Composite Laminates," *NASA Tech. Paper 1751*, Langley Res. Ctr., Hampton, VA (1980).

117. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 1: Homogeneous Plates," *J. Appl. Mechanics, Trans. ASME*, 44, pp 662-668 (1977).

118. Lo, K.H., Christensen, R.M., and Wu, E.M., "A Higher-Order Theory of Plate Deformation; Part 2: Laminated Plates," *J. Appl. Mechanics, Trans. ASME*, 44, pp 669-676 (1977).

119. Spilker, R.L., "Higher Order Three-Dimensional Hybrid-Stress Elements for Thick-Plate Analyses," *Intl. J. Numer. Methods Engr.*, 17, pp 53-69 (1981).

120. Altus, E., Rotem, A., and Shmueli, M., "Free Edge Effect in Angle Ply Laminates - A New Three Dimensional Finite Difference Solution," *J. Composite Matls.*, 14, pp 21-30 (1980).

# LITERATURE REVIEW:

survey and analysis  
of the Shock and  
Vibration literature

The monthly Literature Review, a subjective critique and summary of the literature, consists of two to four review articles each month, 3,000 to 4,000 words in length. The purpose of this section is to present a "digest" of literature over a period of three years. Planned by the Technical Editor, this section provides the DIGEST reader with up-to-date insights into current technology in more than 150 topic areas. Review articles include technical information from articles, reports, and unpublished proceedings. Each article also contains a minor tutorial of the technical area under discussion, a survey and evaluation of the new literature, and recommendations. Review articles are written by experts in the shock and vibration field.

This issue of the DIGEST contains an article about vortex shedding from cylinders and the resulting unsteady forces and flow phenomena.

Ms. S.T. Fleischmann and Professor D.W. Sallet of the University of Maryland, College Park, Maryland have written the second part of a two-part paper that presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration.

## VORTEX SHEDDING FROM CYLINDERS AND THE RESULTING UNSTEADY FORCES AND FLOW PHENOMENA PART II

S.T. Fleischmann and D.W. Sallet\*

*Abstract. This two-part paper presents an extensive review of the unsteady flow phenomena that occur on and near cylinders in cross flow and that are related to vortex shedding. Part II introduces vortex shedding from non-circular cylinders and the topic of cylinders undergoing flow-induced vibration. Experimental values of the unsteady lift and drag coefficients and experimental values of the Strouhal number for circular cylinders over a wide range of Reynolds numbers obtained from numerous investigators are presented.*

### VORTEX SHEDDING FROM NON-CIRCULAR CYLINDERS

The preceding section treated only vortex shedding from circular cylinders. Most measurements have been made using circular cylinders, but considerable data for cylinders of non-circular cross section (that is, of other basic shapes used in structures) also exist. Attempts have been made to correlate data from other shapes with that from circular cylinders through the development of a universal Strouhal number. So that it will be applicable to all bluff bodies from which vortex shedding occurs, this universal Strouhal number is based on wake parameters rather than free-stream velocity and cylinder dimensions. Various studies of vortex shedding from cylinders of non-circular cross sections are considered and the universal Strouhal number developed by three investigators are discussed below.

Knauss, John, and Marks [51] studied vortex shedding from elliptical cylinders having small eccentricity and from square cylinders at various angles of attack in the low Reynolds number range ( $300 \leq Re \leq 1200$ ). It should be noted that the results from

elliptical cylinders should correspond most closely with those of circular cylinders because, as Knauss noted, the absence of a sharp edge allows the separation line to vary. For cylinders with sharp edges separation usually occurs along those edges. It was found [51] that, for elliptical cylinders with an eccentricity between 0.6 and 0.8 at zero angle of incidence, the data for  $Re \leq 500$  are well represented by Roshko's relation for circular cylinders:  $F = 0.212 (Re) - 2.7$ . Above  $Re = 500$ , the best fit equation was a power law relationship  $F = 0.27 (Re_{do})^{0.98}$  similar to Roshko's relation. For square cylinders there is a sudden drop in the Strouhal number as the angle of incidence increases beyond about  $30^\circ$  for various Reynolds numbers; this drop has been attributed to a detachment of the flow from the cylinder [51]. Huthloff [52] recently presented extensive measurements of the Strouhal number and the alternating lift coefficient for various cross sections, including circular cross sections, in the Reynolds numbers range of  $10^4$  to  $10^5$ . For non-circular cylinders he gave the lift coefficient and the Strouhal number as a function of angle of attack for various Reynolds numbers. He found that cylinders having square, rectangular, semicircular, or hexagonal cross sections experienced periodic forces that are considerably higher than those of circular cylinders. This is perhaps not surprising because all of the non-circular cylinders had sharp edges that would tend to define the separation line and therefore correlate the flow along the span of the cylinder. Highly correlated flow would then result in higher periodic forces. Representative results for  $C_L$  presented by Hothloff [52] are shown in Figure 11.

Lee [53] studied the effect of free-stream turbulence on vortex shedding and drag on square cylinders. He also presented a study of the effects of varying

\*Department of Mechanical Engineering, The University of Maryland, College Park, MD 20742.

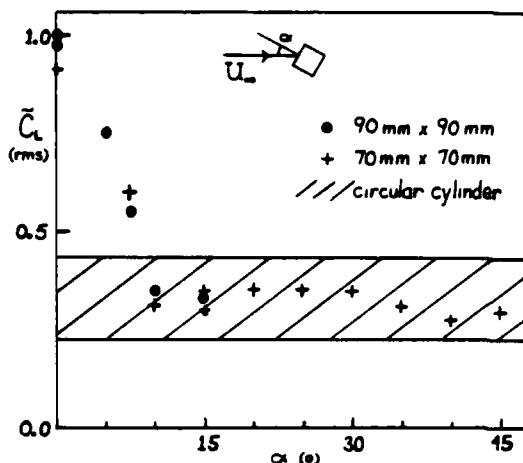


Figure 11. Representative Results [52] Showing Increased Lift Coefficient for Square Cylinders at Small Angles of Attack as Compared to Similar Results for Circular Cylinders ( $4.2 \times 10^4 \leq Re \leq 1.8 \times 10^5$ ).

the angle of attack of square cylinders that included careful measurements of the pressure distribution on the faces of the square made with multiple, equally-spaced pressure sensors. Rockwell [32] also studied vortex shedding from square cylinders at various angles of attack and found that the low frequency modulation of the lift coefficient was due to unstable reattachment of the flow near the end of the cylinder wall.

Twigg-Molecey and Baines [54] measured the Strouhal number as a function of Reynolds number for triangular cylinders in the range  $9 \times 10^3 \leq Re \leq 4 \times 10^4$ . They used pressure measurements on the cylinder face to obtain the periodic coefficients of lift and moment. These studies are presented as typical examples and to illustrate the general problem of vortex shedding from non-circular cylinders. The papers by Knauss [51] and Huthloff [52] contain numerous references to other work in this area.

In all of the studies mentioned (with the exception of the elliptical cross section at low Reynolds numbers) the  $S = S(Re)$  relationship was found to be different from that for circular cylinders. Figure 12, which shows Roshko's data for a circular cylinder, a

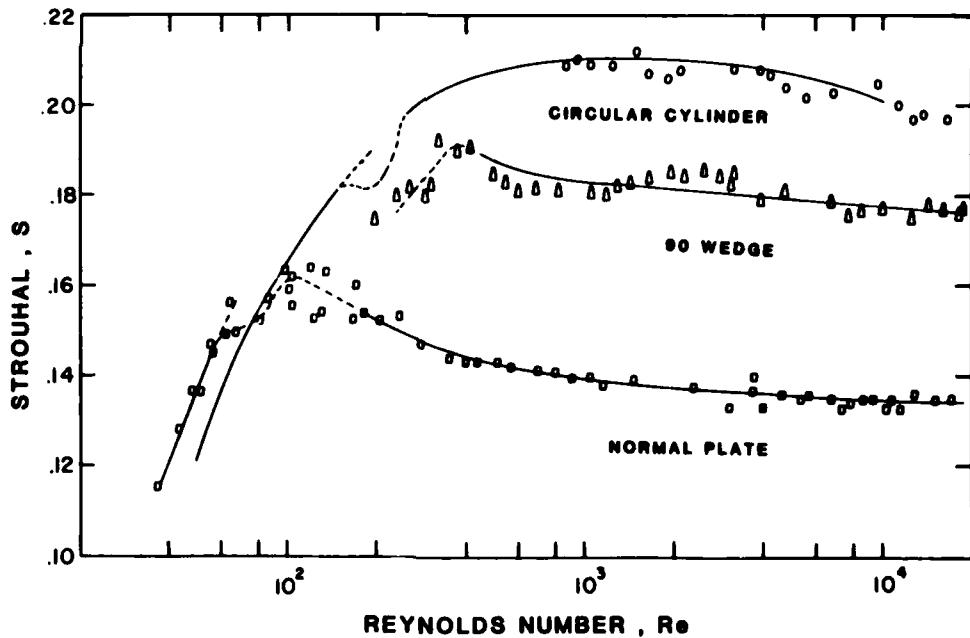


Figure 12. Roshko's Measurement of  $S = S(Re)$  for Various Geometries [55].

90° wedge, and a flat plate illustrates this point. One way to correlate all of the bluff body data is to base the Strouhal number and the Reynolds number on wake parameters rather than on cylinder and upstream flow parameters. It is expected that such a Strouhal number will be universal; that is, it will apply to all bluff bodies.

In 1953, Roshko [55] found that his data for cylinders, flat plates, and 90° wedges were well correlated if they were presented using a wake Strouhal number and a wake Reynolds number. The characteristic length used in each of these numbers was  $h'$ , the separation distance of the shear layers when they become parallel. This distance was calculated using notched hodograph theory. The free stream velocity  $U_\infty$  was not used; rather, the velocity at the point of separation  $U_b$  was used where  $U_b$  was found using Bernoulli's equation and the measured base pressure coefficient  $C_{bp}$ .

$$\frac{U_b}{U_\infty} = (1 - C_{bp})^{1/2}$$

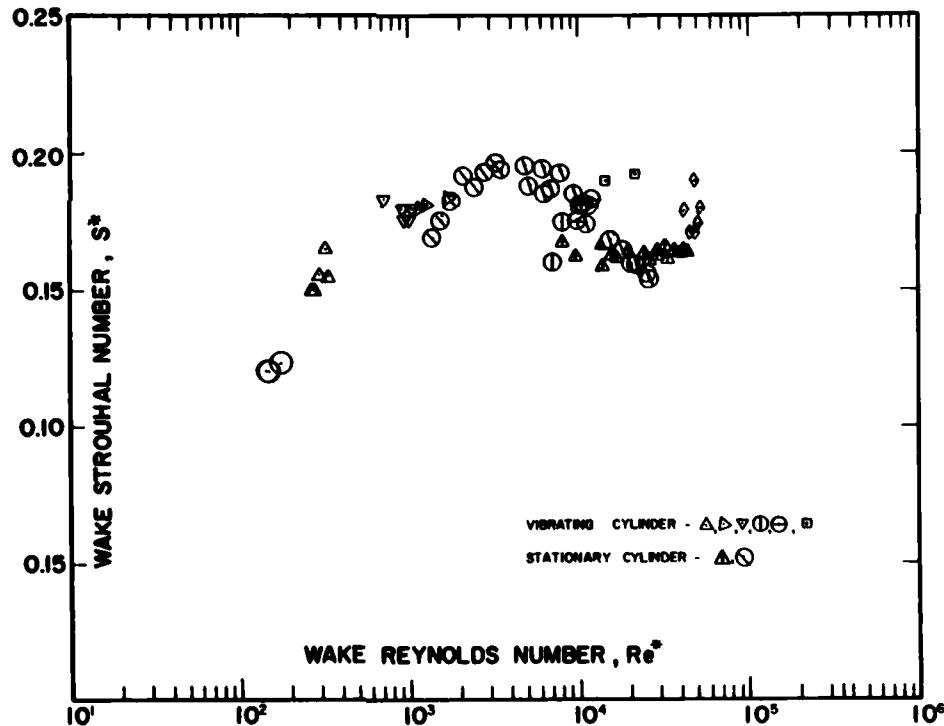


Figure 13. Wake Strouhal Number vs. Wake Reynolds Number. For stationary cylinders [54]:  $\Delta$ , triangular cross section-Roshko;  $\circ$ , circular cylinder-Roshko; for vibrating cylinders [56]:  $\Delta$ , Griffin and Ramberg-1974;  $\blacktriangleright$ , Griffin et al-1973;  $\nabla$ , Griffin and Ramberg-1976;  $\ominus$ , Tanida et al-1973;  $\Theta$ , Stansby-1976;  $\square$ , Meyers-1975;  $\odot$ , Tanida et al-1973.

Roshko's wake Strouhal number is

$$S^* = \frac{f h'}{U_b} = S \frac{U_\infty h'}{U_b d}$$

and his wake Reynolds number is

$$Re^* = \frac{U_b h'}{\nu} = Re \frac{h' U_b}{d U_\infty}$$

where  $d$  is the cylinder dimension and  $Re$  and  $S$  are the usual Reynolds number and Strouhal number based on free-stream velocity and cylinder dimensions. Roshko's results using the wake parameters discussed are shown in Figure 13; the good correlation is evident.

Bearman [56] later noted that Roshko's formulation assumes that the vortices form from shear layers at the spacing predicted by notched hodograph theory. He further noted that, in such cases as near-wake interference, the commencement of vortex shedding is delayed to a point downstream of the cylinder and that the separation of the shear layers

at that point is not equal to the shear layer separation obtained from notched hodograph theory. Bearman then defined a new universal Strouhal number based on the distance  $h''$  between the shear layer at the commencement of vortex shedding. This distance  $h''$  is equal to the lateral spacing  $h$  in the vortex street. Bearman's universal Strouhal number is defined as:

$$S_B = \frac{fh}{U_b} = \frac{Sh}{d} \frac{U_\infty}{U_b}$$

The ratio  $\frac{h}{d}$  can be found using the stability criterion proposed by either von Karman ( $h/\ell = .281$ ) or Kronauer

$$\frac{\partial C_D}{\partial (h/\ell)} \Big|_{U_S} = 0$$

$$\frac{U}{U_\infty}$$

$C_D$  is Karman's analytical expression. Bearman found the best correlation by using the Kronauer stability criterion to determine  $\frac{h}{\ell}$ ; the shedding frequency and base pressure coefficient were experimentally obtained.

Both Roshko's and Bearman's formulations apply to stationary cylinders. Griffin [57] recently extended the concept of the universal Strouhal number to the case of freely vibrating cylinders. In his formulation the length parameter  $h'$  was the measured distance between the shear layers at the end of the vortex formation region. His results using his own data and the data of other investigators are given in Figure 13; there is good agreement with results for stationary cylinders of various cross sections.

### VIBRATING CYLINDERS

The periodic forces due to vortex shedding from a cylinder in cross flow and the various flow regimes for a rigidly supported circular cylinder – that is, a cylinder for which the flow-cylinder interaction is restrained – have been described. The question now arises: what happens when flow-cylinder interaction is allowed and the cylinder vibrates. The question is relevant to all disciplines of engineering because costly structural damage can occur due to vortex-induced resonant motions of elastically-supported structural members; more knowledge in this area is needed.

Berger and Willie [37] reviewed the work in vibrating cylinders up to 1972 and Mair and Maull [40] reported on results presented at Euromech 17. Brief introductory reviews of more recent work are available [58, 59]. A scheme for the classification and analysis of flow-induced vibration problems has been given [60]. Numerous conferences concerning flow-induced vibrations in the past 10 years attest to the continued research interest in this problem [61-65]. This section considers flow-induced cylinder vibration; emphasis is on the physical processes involved.

It should be noted that the flow-cylinder interaction is extremely complex and highly nonlinear. The motion of the cylinder changes the geometry of the vortex wake and the periodic fluid forces on the cylinder. In turn, the changes in the periodic forces change the cylinder motion. Because the flow-cylinder interaction is so complex, results obtained from experiments in which the frequency and amplitude of vibration are externally controlled are often applied to the case of flow-induced vibration. Such applications must be done very carefully. Griffin [66] has shown that the near wake and the phase relation between the flow field and the cylinder motion are essentially the same for cylinders under forced and flow-induced vibrations if the Reynold's number and the frequency and amplitude of vibration are matched.

For small amplitude vibrations increased span-wise correlation in flow has been reported [24, 37, 67]. The increased span-wise correlation makes the flow more strongly two-dimensional and therefore increases the lift force on the cylinder. In experiments on forced vibrating cylinders Griffin and Ramberg [30] noted that when the ratio of vibration amplitude to cylinder diameter,  $a/d$ , is less than 50% (within the range of observed resonant response to flow-induced vibrations) the circulation of the vortices increases and the length of formation decreases. Bearman [56] found a nearly inverse relation between the base pressure coefficient (and therefore the drag) and the length of formation. Increased steady drag for a vibrating cylinder has been observed.

When the vortex shedding frequency is sufficiently close to the natural frequency of an elastically mounted cylinder or structural member, the vortex

shedding frequency,  $f$ , and the natural frequency become synchronized; that is, the Strouhal frequency,  $f_s$ , is suppressed and for a range of Reynold's numbers the shedding frequency is equal to the natural frequency of the cylinder system. This phenomenon is known as lock-in or wake capture. It is under conditions of lock-in that large amplitude resonant vibrations are observed.

Umemura, Yamaguchi, and Shiraki [68] used a spring mounted circular cylinder to investigate the amplitude response and the limits of lock-in as a function of external damping. They presented the amplitude response and the frequency of vortex shedding for the same cylinder under three different conditions of damping. For the highly damped system they found that almost no lock-in occurred. When damping was decreased by about an order of magnitude, lock-in occurred when the Strouhal frequency reached the system's natural frequency and persisted over a short range of higher Reynold's numbers, after which the shedding frequency abruptly returned to the Strouhal frequency. When the damping was decreased by yet another order of magnitude, lock-in occurred over the entire range of Reynold's numbers tested, both below and above  $V^*$ , the free-stream velocity for which the Strouhal and natural frequencies are equal. The maximum amplitude of vibration increased by roughly an order of magnitude each time the damping was decreased by about an order of magnitude. Furthermore the flow speed at which the maximum amplitude occurred increased with decreased external damping.

Although the flow speed,  $V_{max}$ , for which the maximum amplitude occurred was different for the three cases quoted, and the maximum amplitude was different, the flow speed range over which pronounced resonant vibration occurred relative to  $V_{max}$  seemed to be about the same ( $\pm 1\text{m/sec}$ ) in all cases. For cases of high and medium damping the vibration built up and died down outside the region of lock-in, but the maximum amplitude of vibration occurred in the region of lock-in.

Feng and Parkinson [69], in experiments with spring mounted cylinders of circular and D-section, observed similar behavior in their investigation of lock-in for the case of the circular cylinder. They also found that the free-stream velocity for which the maximum amplitude was attained was lower

when the velocity was gradually decreased than when it was gradually increased through the lock-in region. Feng and Parkinson [69] also observed that, while lock-in occurred mostly above  $V^*$  for circular cylinders, it occurred mostly below  $V^*$  for the D-section cylinders.

All cylinders experience fluid damping in addition to external mechanical damping. Griffin and Koopmann [59] reported a rapid decrease in fluid damping just before lock-in and a rapid increase immediately thereafter. Skop, Ramberg, and Ferer [70] have discussed the measurement and evaluation of fluid damping and added mass.

The amplitude and frequency response of spring mounted and externally damped cylinders that were free to vibrate perpendicular to the flow direction in water have been studied by Meier-Windhorst [71]. Similar results for spring mounted cylinders in air have been obtained by Glass [72] and others [58, 59]. Toebees and Eagleston [73] showed experimentally that the amplitude response of non-circular bluff bodies depends in general on the trailing edge geometry.

Throughout the lock-in region (with the exception of possibly one point) the shedding frequency is different from the Strouhal frequency observed for stationary cylinders. Because the shedding frequency is different, the longitudinal spacing of the wake vortices will also be different from that in the wake of stationary cylinders. In an extension of the two-dimensional Karman model to cylinders under small amplitude vibrations Sallet [14] noted that, for constant lateral spacing, an increase in longitudinal spacing leads to an increase in lift and vice versa. The Karman model also shows that, at constant longitudinal spacing (shedding frequency), changes in lateral spacing change the lift. In observations of cylinders under forced vibration Griffin and Ramberg [30] confirmed earlier observations [28] that, at constant vibration frequency, an increase in cylinder amplitude results in a decrease in lateral vortex spacing and that, at constant amplitude, the longitudinal spacing varies inversely with vibration frequency. The lateral spacing for a cylinder forced to vibrate at 85% of the Strouhal frequency approached zero as  $a/d$  approached 0.5 [30]. Further increases in the amplitude caused serious distortions of the wake. For vibration frequencies closer to the Strou-

hal frequency the critical vibration amplitude for which serious disorders in the wake first appeared also increased. It is possible that the approach to zero lateral spacing poses a limit to the amplitude of flow-induced vibration.

In accord with the observed resonant amplitude response of an elastically-supported cylinder under conditions of lock-in, Griffin and Koopmann [59] showed that the coefficient of lift increases to a maximum of  $C_L^* = 0.5$  to  $0.6$  and then gradually decreases as the Reynolds number is slowly increased through the region of lock-in. Bishop and Hassan [74] showed that  $C_L^*$  for a vibrating cylinder is greater than  $C_L$  for a stationary cylinder before the maximum amplitude is reached and that  $C_L^*$  was less than  $C_L$  afterward.

Griffin, Skop, and Koopmann [58] noted that the energy transfer from the fluid to the cylinder is positive when the lift force has a component in phase with the cylinder motion. They used measurements to show that maximum energy transfer occurs when the maximum amplitude is obtained. It has been reported [58, 59, 74, 75] that a phase shift of about  $90^\circ$  occurs as the lock-in region is traversed; i.e., a phase shift of cylinder motion relative to the lift force.

The amplitude response of a cylinder in cross flow is evidently complex. The most successful model of cylinder motion has been the wake oscillator model, which was introduced by Hartlan and Currie [76] and further developed by Skop and Griffin [77]. An introduction to the model and further references are available [2, 3, 58, 59].

The focus of this paper has been the periodic forces on a cylinder in cross flow. Not only do the periodic forces due to cylinder vibration change but the steady drag force is also increased. Sallet [14] in his extension of the Karman model to vibrating cylinders noted a general trend to increased steady drag as cylinder amplitude increases. Tanida, Okajima, and Watanabe [78] have measured the increased drag experienced by a forced vibrating circular cylinder that was towed through water. Griffin, Skop, and Koopmann [58] measured an increased steady drag for freely vibrating cylinders. Griffin and Ramberg [30] found an inverse relation between the length of formation and the steady drag and reported

increased steady drag when the cylinder vibrates. Additional information is available [3].

Both the periodic forces and the steady forces change radically as a cylinder vibrates; flow-cylinder interaction is extremely complex. The topic of flow-induced vibrations is a topic of current research and much work remains in this area.

#### ACKNOWLEDGMENT

The authors wish to acknowledge the Minta Martin committee at the University of Maryland for their support during the writing of this paper and for their continuing support of further research in this area.

#### REFERENCES

1. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part I: Stationary Fluids and Parallel Flow," *Shock Vib. Dig.*, 9 (10), pp 25-38 (Oct 1977).
2. Chen, S.S., "Flow-induced Vibrations of Circular Cylindrical Structures. Part II: Cross-flow Considerations," *Shock Vib. Dig.*, 9 (11), pp 21-27 (Nov 1977).
3. Blevins, R.D., Flow-induced Vibration, Von Nostrand Reinhold (1977).
4. Rubach, H.L., "Ueber die Entstehung und Fortbewegung des Wirbelpaares hinter zylindrischen Körpern," *Forschungsarbeiten auf dem Gebiete des Ingenieurwesens, Verein Deutscher Ingenieure*, Heft 185, Berlin (1916).
5. Foppl, L., "Wirbelbewegung hinter einem Kreiszylinder," *Sitzungsberichte der mathematisch-physikalischen Klasse der Königlich Bayerischen Akademie der Wissenschaften, München*, pp 1-17 (1913).
6. Strouhal, V., "Über Eine Besondere Art der Tonnerregung," *Ann. Phys. Chemie, Neue Folge*, Bd. 5, Heft 10, pp 216-251 (Oct 1878).
7. von Karman, T. and Rubach, H., "Über den Mechanismus des Flüssigkeits und Luftwider-

standes," *Physikalische Zeitschrift*, 13 (2), pp 49-59 (Jan 1912).

8. Bernard, H., "Formation de Centres de Giration à l'arriète d'un Obstacle en Mouvement," *Comp. Rend.*, Acad. Sci. (Paris), 147, pp 839-842 (Nov 9, 1908).

9. von Kármán, T., "Über den Mechanismus des Widerstandes den ein bewegter Körper in einer Flüssigkeit erfährt," *Nachrichten der K. Gesellschaft der Wissenschaften zu Göttingen; Mathematisch-Physikalische Klasse*, pp 509-517 (1911).

10. Ibid., pp 547-556 (1912).

11. Krzywoblocki, M.Z., "Vortex Streets in Fluids," *Applied Mechanics Surveys*, edited by H. Horman Abramson, Harold Leibowitz et. al., Spartan Books, pp 885-892 (1966).

12. Sallet, D.W., "On the Prediction of Flutter Forces," Contribution to Flow-Induced Structural Vibrations, E. Naudascher, editor (Symp., Karlsruhe, Germany, Aug 1972) Springer Verlag, pp 159-176.

13. Sallet, D.W., "The Lift Force due to von Kármán's Vortex Wake," *J. Hydraulics*, 7 (4), pp 161-165 (Oct 1973).

14. Sallet, D., "The Drag and Oscillating Transverse Force on Vibrating Cylinders due to Steady Fluid Flow," *Ing. Arch.*, 44, pp 113-122 (1975).

15. Sallet, D., "On the Spacing of Kármán Vortices," *J. Appl. Mechanics, Trans. ASME*, pp 370-372 (June 1969).

16. Bearman, P.W., "On Vortex Street Wakes," *J. Fluid Mechanics*, 28, pt 4, pp 625-641 (1967).

17. Griffin, O., "On Vortex Strength and Drag in Bluff-Body Wakes," *J. Fluid Mechanics*, 69, pt 4, pp 721-728 (1975).

18. Jendrzejczyk, J.A. and Chen, S.S., "Fluid Forces Acting on Circular Cylinders in Liquid Cross-flow," *Tech. Mem. ANL-CT-81-13*, Argonne Nat'l Lab. (Dec 1980).

19. Keefe, R.T., "Investigation of the Fluctuating Forces Acting on a Circular Cylinder in a Subsonic Stream and the Associated Sound Field," *J. Acoust. Soc. Amer.*, 34 (11), pp 1711-1714 (Nov 1962).

20. Okamoto, T. and Yagita, M., "The Experimental Investigation on the Flow Past a Circular Cylinder of Finite Length Placed Normal to the Plane Surface in a Uniform Stream," *Bull. JSME*, 16 (95), pp 805-814 (May 1973).

21. Humphreys, J.S., "On a Circular Cylinder in a Steady Wind at Transition Reynolds Numbers," *J. Fluid Mechanics*, 9, pt 4, pp 603-612 (1960).

22. Hussain, AKMF and Ramjee, V., "Periodic Wake Behind a Circular Cylinder at Low Reynolds Numbers," *Aeronaut. Quart.*, 27, pt 2, pp 123-142 (May 1976).

23. Schubauer, G.B. and Skramstad, H.K., "Laminar Boundary-Layer Oscillations and Transition on a Flat Plate," *NACA Rep. 909* (1943).

24. Toeves, G.H., "The Unsteady Flow and Wake Near an Oscillating Cylinder," *J. Basic Engr.*, pp 493-505 (Sept 1969).

25. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Cylinders," *J. Engr. Indus., Trans. ASME*, pp 539-547 (May 1972).

26. Gaster, M., "Vortex Shedding from Slender Cones," *J. Fluid Mechanics*, 38, pt 3, pp 565-576 (1969).

27. Umemura, S., Yamaguchi, T., and Shirai, K., "On the Vibration of Cylinders Caused by Karman Vortex," *Bull. JSME*, 14 (75), pp 929-937 (1971).

28. Koopmann, G.H., "The Vortex Wakes of Vibrating Cylinders at Low Reynolds Numbers," *J. Fluid Mechanics*, 28, pp 501-512 (1967).

29. Griffin, O.M. and Votaw, C.W., "The Vortex Street in the Wake of a Vibrating Cylinder," *J. Fluid Mechanics*, 55, pp 31-48 (1972).

30. Griffin, O.M. and Ramberg, S.E., "The Vortex Street Wakes of Vibrating Cylinders," *J. Fluid Mechanics*, 66, pt 3, pp 553-576 (1974).

31. Thomas, D.G. and Kraus, K.A., "Interaction of Vortex Streets," *J. Appl. Physics*, 35 (12), pp 3458-3459 (Dec 1964).

32. Rockwell, D.O., "Organized Fluctuations due to Flow Past a Square Cross-Section Cylinder," *J. Fluids Engr., Trans. ASME*, 99 (3), pp 511-516 (Sept 1977).

33. Roshko, A., "On the Development of Turbulent Wakes from Vortex Streets," *NACA Tech. Note* 2913 (Mar 1953).

34. Nishioha, M. and Sato, H., "Mechanism of Determination of the Shedding Frequency of Vortices behind a Cylinder at Low Reynolds Numbers," *J. Fluid Mechanics*, 89, pt 1, pp 49-60.

35. Goldstein, S. (Ed), Modern Developments in Fluid Mechanics, vol. II, Dover Publ. (1965).

36. Tritton, D.J., "Experiments on the Flow Past a Circular Cylinder at Low Reynolds Numbers," *J. Fluid Mechanics*, 6, pt 4, pp 547-560.

37. Berger, E. and Wille, R., "Periodic Flow Phenomena," *Ann. Rev. Fluid Mechanics*, 4, pp 313-340 (1972).

38. Marrow, T.B. and Kline, S.J., "The Evaluation and Use of Hot-wire and Hot Film Anemometers in Liquids," *Stanford Univ. Rep. MD-25* (1971).

39. Kohan, S. and Schwarz, W.H., "Low Speed Calibration Formula for Vortex Shedding from Cylinders," *Physics Fluids*, 16, pp 1528-1529 (1973).

40. Mair, W.A. and Maull, D.J., "Bluff Bodies and Vortex Shedding - a Report on Euromech 17," *J. Fluid Mechanics*, 45, pt 2, pp 209-224 (1971).

41. Tritton, D.J., "A Note on Vortex Streets behind Circular Cylinders at Low Reynolds Numbers," *J. Fluid Mechanics*, 45, pt 1, pp 203-208 (1971).

42. Taneda, S., "Experimental Investigation of the Wakes behind Cylinders and Plates at Low Reynolds Numbers," *J. Phys. Soc. Japan*, 11, p 1284 (1956).

43. Gerrard, J.H., "The Mechanics of the Formation Region of Vortices behind Bluff Bodies," *J. Fluid Mechanics*, 25, pt 2, pp 401-413.

44. Jaminet, J.F. and Van Atta, C.W., "Experiments on Vortex Shedding from Rotating Circular Cylinders," *AIAA J.*, 7 (9), pp 1817-1819.

45. Schiller, L. and Linke, W., "Druck-und Reibungswiderstand des Zylinders bei Reynolds-Zahlen 5000 bis 40000," *Z.F.M.*, Jahrg. 24, Nr. 7, pp 193-198 (Apr 13, 1933) (in English-NACA TM 715).

46. Bearman, P.W., "On Vortex Shedding from a Circular Cylinder in the Critical Reynolds Number Regime," *J. Fluid Mechanics*, 3, pt 3, pp 577-585.

47. Jones, G.W., Cincotta, J.J., and Walker, R.W., "Aerodynamic Forces on Stationary and Oscillating Circular Cylinders at High Reynolds Numbers," *NASA TR R-300* (Feb 1969).

48. Schmitt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," *J. Aircraft*, 2 (1), pp 49-55 (Jan/Feb 1965).

49. Schlinker, R.H., Fink, M.R., and Amiet, R.K., "Vortex Noise from Non-Rotating Cylinders and Airfoils," *AIAA Paper 76-81* (Jan 1976).

50. Roshko, A., "Experiments on the Flow Past a Circular Cylinder at Very High Reynolds Number," *J. Fluid Mechanics*, 10, pp 345-356.

51. Knauss, D.T., John, J.E.A., and Marks, C.H., "The Vortex Frequencies of Bluff Cylinders at Low Reynolds Numbers," *J. Hydraulics*, 10 (4), pp 121-126 (Oct 1976).

52. Huthloff, E., "Windkanaluntersuchungen zur Bestimmung der periodischen Kräfte bei der Umströmung schlanker scharfkantiger Körper," *Stahlbau*, 44 (4), pp 97-103 (Apr 1975).

53. Lee, B.E., "The Effect of Turbulence on the Surface Pressure Field of a Square Prism," *J. Fluid Mechanics*, 69, pt 2, pp 263-282.

54. Twigge-Molecey, C.F.M. and Baines, W.D., "Aerodynamic Forces on a Triangular Cylind-

der," ASCE J. Engr. Mechanics Div., 99 (EM 4), pp 803-818 (Aug 1973).

55. Roshko, A., "On the Drag and Shedding Frequency of Two-Dimensional Bluff Bodies," NACA TN 3169 (July 1954).

56. Bearman, P.W., "On Vortex Street Wakes," J. Fluid Mechanics, 28, pt 4, pp 625-641.

57. Griffin, O.M., "Universal Strouhal Number for the 'Locking-on' of Vortex Shedding to the Vibrations of Bluff Cylinders," J. Fluid Mechanics, 85, pt. 3, pp 591-606 (Apr 1978).

58. Griffin, O.M., Skop, R.A., and Koopmann, G.H., "The Vortex Excited Resonant Vibrations of Circular Cylinders," J. Sound Vib., 31 (2), pp 235-249 (1973).

59. Griffin, O.M. and Koopmann, G.H., "The Vortex Excited Lift and Reaction Forces on Resonantly Vibrating Cylinders," J. Sound Vib., 54 (3), pp 435-448 (1977).

60. Naudascher, E. and Rockwell, D., "Oscillator Model Approach to the Identification and Assessment of Flow-Induced Vibrations in a System," J. Hydraul. Res., 18 (1), pp 59-82 (1980).

61. Proc. IUTAM-IAHR Symp. Flow-Induced Struct. Vib., Karlsruhe, Germany (1972).

62. Sallet, D.W., "Symposium on Practical Experiences with Flow-Induced Vibrations," Karlsruhe, Germany (Sept 3-6, 1979), Shock Vib. Dig., 12 (1), pp 36-40 (Jan 1980).

63. Proc. Flow-Induced Vibrations Symp., 3rd Natl. Congress Pressure Vessel Piping Tech., San Francisco, Cal., June 25-29, 1979, publ. by ASME (1979).

64. E Naudascher (ed), Flow-Induced Structural Vibrations, Springer-Verlag (1974).

65. Eaton, K.J., (ed), Proc. the 4th Intl. Conf. Wind Effects Bldgs. Struct., Heathrow (1975), Cambridge Univ. Press.

66. Griffin, O.M., "Flow near Self-Excited and Forced Vibrating Circular Cylinders," J. Engr. Indus., Trans. ASME, 94, pp 539-547 (May 1972).

67. Dale, J.R. and Holler, R.A., "Vortex Wakes from Flexible Circular Cylinders at Low Reynolds Numbers," 1-225 974, copy 1, U.S. Naval Air Dev. Center, Johnsville, Warminster, PA.

68. Umemura, S., Yamaguchi, T., and Shiraki, K., "On the Vibration of Cylinders Caused by Karman Vortex," Bull. JSME, 14 (75), pp 929-937 (1971).

69. Feng, C.C. and Parkinson, G.V., paper given at Euromech 17 (1970).

70. Skop, R.A., Ramberg, S.E., and Ferer, K.E., "Added Mass and Damping Forces on Circular Cylinders," NRL Report 7970 (Mar 19, 1976).

71. Meier-Windhorst, A., "Flatterschwingungen von Zylindern im gleichmässigen Flüssigkeitsstrom," Mitteilungen des Hydraulischen Instituts der Technischen Hochschule München, Heft 9, pp 1-29 (1939).

72. Glass, R., "A Study of the Self-Excited Vibrations of Spring Supported Cylinders in a Steady Fluid Stream," Doctoral Thesis, Univ. Maryland (1966).

73. Toebe, G.H. and Eagleston, P.S., "Hydroelastic Vibrations of Flat Plates Related to Trailing Edge Geometry," J. Basic Engr., Trans. ASME, pp 671-678 (Dec 1961).

74. Bishop, R.E.D. and Hassan, A.Y., "The Lift and Drag Forces on a Circular Cylinder Oscillating in a Flowing Fluid," Proc. Royal Soc. (London), Ser. A, 277, pp 51-75 (1964).

75. Diana, G. and Falco, M., "On the Forces Transmitted to a Vibrating Cylinder by a Blowing Fluid," Meccanica, 6, pp 9-22 (1971).

76. Hartlan, R. and Currie, I., "A Lift-Oscillator Model for Vortex Induced Vibrations," ASCE J. Engr. Mechanics Div., 96, pp 571-591 (1970).

77. Skop, R.A. and Griffin, O.M., "A Model for the Vortex-Excited Resonant Vibrations of Bluff Bodies," *J. Sound Vib.*, 27, pp 225-233 (1973).
78. Tanida, Y., Okajima, A., and Watanabe, Y., "Stability of a Circular Cylinder Oscillating in Uniform Flow or in a Wake," *J. Fluid Mechanics*, 61, pt 4, pp 769-784.
79. Kovaznay, L.G.S., "Hot-Wire Investigation of the Wake Behind Cylinders at Low Reynolds Numbers," *Proc. Royal Soc., (London) Ser. A*, 198 (1053), pp 174-190 (1949).
80. Hanson, A.R., "Vortex Shedding from Yawed Cylinders," *AIAA J.*, 4 (4), pp 738-740.
81. Lutz, H.J. and Haussling, H.J., "Laminar Flows Past a Flat Plate at Various Angles of Attack," Lecture Notes (no. 8) in Physics, Springer-Verlag (1971).
82. Jordan, S.K. and Fromm, J.E., "Oscillating Drag Lift and Torque on a Circular Cylinder in a Uniform Flow," *Physics Fluids*, 15 (3), pp 371-376 (Mar 1972).
83. McGregor, O.M., "An Experimental Investigation of the Oscillating Pressures on a Circular Cylinder in a Fluid Stream," UTIA. Tech. Note No. 14 (June 1957).
84. Gerrard, J.H., "An Experimental Investigation of the Oscillating Lift and Drag of a Circular Cylinder Shedding Turbulent Vortices," *J. Sound Vib.*, pp 244-256.
85. Relf, E.F. and Simmons, L.F.G., "The Frequency of the Eddies Generated by the Motion of Circular Cylinders through a Fluid," *Aeronaut. Res. Comm. (London)*, R and M, no. 917 (June 1924).
86. Drescher, H., "Messung der auf Querangeströmte Zylinder Ausgeübten Zeitlich Veränderten Drücke," *Z. Flugwiss.*, 4, Heft 1/2, p 17 (1956).
87. Delany, M.K. and Sorenson, M.E., "Low Speed Drag of Cylinders of Various Shapes," NACA TN 3038 (1953).
88. Warren, W.F., "An Experimental Investigation of Fluid Forces of an Oscillating Cylinder," Ph.D. Thesis, Univ. Maryland (1962).
89. Kuwahara, K., "Study of Flow Past a Circular Cylinder by an Inviscid Model," *J. Phys. Soc. Japan*, 45 (1), pp 292-297 (July 1978).
90. Takao, Y., IBM Japan Sci. Ctr., Rep. G318-1909-0 (1973).
91. Fung, Y.C., "Fluctuating Lift and Drag Acting on a Cylinder in a Flow at Supercritical Reynolds Numbers," *J. Aerospace Sci.*, 27 (11), pp 801-814 (Nov 1960).
92. Schmidt, L.V., "Measurements of Fluctuating Air Loads on a Circular Cylinder," *J. Aircraft*, 2 (1), pp 49-55 (Jan/Feb 1965).
93. Schlichting, H., Boundary Layer Theory (6th ed), McGraw-Hill, p 17, fig. 1.4.

# ANNUAL ARTICLE INDEX

## FEATURE ARTICLES

	ISSUE	PAGES
Munjal, M.L. <b>Evaluation and Control of the Exhaust Noise of Reciprocating I.C. Engines</b>	1	5-14
GangaRao, H.V.S. and Haslebacher, C.A. <b>Vibration Analysis of Highway Bridges</b>	2	3-8
Wittlin, G. <b>Aircraft Crash Dynamics: Some Major Considerations</b>	3	3-15
Markus, S. and Nanasi, T. <b>Vibration of Curved Beams</b>	4	3-14
Fawcett, J.N. <b>Chain and Belt Drives - A Review</b>	5	5-12
DiMaggio, F.L. <b>Dynamic Response of Fluid-Filled Shells - An Update</b>	6	3-6
Ramamurti, V. and Srinivasan, V. <b>Machine Tool Vibration - A Review</b>	7	3-8
Griffin, M.J. <b>Biodynamic Response to Whole-Body Vibration</b>	8	3-12
Ignaczak, J. <b>Linear Dynamic Thermoelasticity - A Survey</b>	9	3-8
Jones, N. <b>Recent Progress in the Dynamic Plastic Behavior of Structures, Part III</b>	10	3-16
Attenborough, K. <b>Sound Attenuation Over Ground Cover III</b>	11	3-6
Reddy, J.N. <b>Finite-Element Modeling of Layered, Anisotropic Composite Plates and Shells: A Review of Recent Research</b>	12	3-12

## LITERATURE REVIEWS

	ISSUE	PAGES
Huseyin, K. <b>Vibrations and Stability of Mechanical Systems: II</b>	1	21-29
Nakra, B.C. <b>Vibration Control with Viscoelastic Materials - II</b>	1	17-20
Etter, P.C. <b>Underwater Acoustic Modeling Techniques</b>	2	11-20
Massoud, M. <b>Impedance Methods for Machine Analysis</b>	3	17-21
Roberts, J.B. <b>Response of Nonlinear Mechanical Systems to Random Excitation. Part I: Markov Methods</b>	4	17-28
Roberts, J.B. <b>Response of Nonlinear Mechanical Systems to Random Excitation. Part 2: Equivalent Linearization and Other Methods</b>	5	15-29
Chang, C.H. <b>Vibrations of Conical Shells</b>	6	9-17
Waberski, A. <b>Method of R-Functions and Its Application to Analysis of Vibrations of Plates and Other Structures</b>	7	11-14
Leis, B.N. and Broek, D. <b>The Role of Similitude in Fatigue and Fatigue Crack Growth Analyses</b>	8	15-28
Ibrahim, R.A. <b>Parametric Vibration. Part VI: Stochastic Problems (2)</b>	9	23-35
Leissa, A.W. <b>Plate Vibration Research, 1976 - 1980: Classical Theory</b>	9	11-22
Leissa, A.W. <b>Plate Vibration Research, 1976 - 1980: Complicating Effects</b>	10	19-36
Fleischmann, S.T. and Sallet, D.W. <b>Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part I</b>	11	9-22
Fleischmann, S.T. and Sallet, D.W. <b>Vortex Shedding from Cylinders and the Resulting Unsteady Forces and Flow Phenomenon. Part II</b>	12	15-24

# BOOK REVIEWS

## STATISTICAL ENERGY ANALYSIS OF DYNAMIC SYSTEMS

R.H. Lyons  
MIT Press, Cambridge, MA

Large and lightweight aircraft and other structures, including houses have focused interest on higher modal analysis for predicting structural fatigue, equipment failure, and noise production. Traditional analyses of mechanical system vibration of machines and structures were concerned with lower resonant modes. Statistical energy analysis (SEA), which is expressed in terms of random parameters, is now being utilized by mechanical and structural engineers.

The prime advantage of SEA is that a large number of modes can be compressed into a few coherent features of the modal pattern (direct field and a few early reflections), and the incoherent pattern (reverberant field) can be compressed into a few frequency bands. In addition, SEA allows for a simple description of a system; modes or waves are used to describe the field.

The 15 chapters of the book are contained in two parts; the numerous references are annotated.

Part I on basic theory consists of four chapters. The history and development of SEA, and single- and multi-degree-of-freedom systems are described. The storage of kinetic and potential energy by modes in free and forced vibration plus the decay or rate of energy removed by damping are considered.

Chapter III introduces the concept of average power flow - average in both ensemble and temporal sense between simple single- and more complicated multi-degree of freedom-systems. The idea of blocked systems, similar to that used in electrical systems, is introduced. Power flow in terms of both blocked and coupled system energies are considered; the idea of enlarged modal interactions as a white noise source is presented.

Chapter IV considers the problems of estimating response using average energy distribution. The estimation of displacement and stresses leads to the development of intervals of estimating and confidence coefficients. This is important when statistical analysis of variance shows that the standard deviation is an appreciable fraction of the mean.

Part II centers upon engineering applications of SEA in predicting vibration. Four chapters discuss response estimation during the early stages in the design of a high-speed flight vehicle; dynamic response of a system in terms of stress, acceleration, and pressure; estimations of the average system energy from the SEA model and knowledge of its parameters. The use of such SEA parameters as loss factor, power transfer parameters, and modal density of a system plus the important input power prediction are described. The ratio of the convection speed of pressure waves to the bending wave speed in a turbulent boundary layer is given.

The next three chapters show how the system can be modeled and define subsystems; included are the identification and evaluation of coupling between systems. Parameter evaluation, which is the engineering basis for SEA, is illustrated by measuring damping in both simple and built-up structures, including constraint layer structures.

The author illustrates the evaluation of coupling loss factors by applying them to aerospace structures, acoustical spaces, cylinders, and coupling between structural subsystems. An example is given of the use of SEA in the response estimation of a re-entry vehicle; information on modal density, high-frequency modal coupling loss factors, and the experimental procedures required to determine the parameters are described.

The reviewer has noticed that the most important uses to date have been in noise control problems, noise propagation in ships, and vibrations in nuclear reactors and enclosed space structures. SEA has a major stumbling block: the determination of param-

eters from experimental tests. The reviewer does recommend this book to engineers involved in this subject. However, more work must be done.

H. Saunders  
General Electric Co.  
Schenectady, NY

## DYNAMICS OF MECHANICAL SYSTEMS

J.M. Prentis  
Halsted Press, New York, NY  
1980, 486 pages, 2nd Edition

This undergraduate text contains material that would typically be found in separate books on machine dynamics, vibrations, and automatic control theory. The entire text would be suitable for a two-semester senior level course; a one semester course could be based on selected chapters. The chapter by chapter contents are as follows:

**Chapter 1 - Simple Mechanisms I.** This short introductory chapter to the first one-third of the book is devoted to the classification of plane and spatial mechanisms.

**Chapter 2 - Simple Mechanisms II.** The practical kinematics of planar mechanisms such as cams, gears, gear trains, and linkages are illustrated. The mathematical presentation is based on elementary calculus, without reference to vectors or complex numbers.

**Chapter 3 - Force Relationships in Mechanisms I Transmitted Forces and Friction.** The first part of this brief chapter considers frictionless mechanisms. The virtual work concept applied to friction is introduced. The chapter concludes with a study of the effects of friction on cams, four-bar, and slider-crank mechanisms.

**Chapter 4 - Velocities and Accelerations.** The vector kinematic relations for moving spatial reference frames are derived at the beginning of the chapter. The relations are then applied mainly to such planar mechanisms as cams and linkages; the concept of equivalent mechanisms is introduced.

**Chapter 5 - Force Relations in Mechanisms II Inertia Forces.** This 60-page chapter covers D'Alembert's principle, balancing concepts, gyroscopic effects, angular momentum, plane motion inertia, transmission of inertia forces, and inertial stresses. Analytical and graphical methods are emphasized.

**Chapter 6 - I First Order Systems.** The automatic control third of the book is introduced with this chapter on lumped parameter modeling. Proportional elements, integrating elements, transfer relations, response, lag, and superposition are described mathematically and physically using differential equations and complex numbers.

**Chapter 7 - II Second Order Systems.** Chapter 7 is a continuation of the previous chapter. The concepts of amplitude, phase, and frequency are described mathematically and illustrated using spring-mass systems and servo-mechanisms.

**Chapter 8 - Automatic Control.** This very long chapter deals with the standard topics of open and closed loop systems, derivative control and integral control, position and speed control, stability criteria, Bode diagrams, and system design. The presentation is mainly theoretical; there are illustrations of the application of the theory to practical systems.

**Chapter 9** constitutes almost one third of the book. It follows logically the modeling techniques introduced in the chapter on automatic control. The classical spring-mass system, isolation techniques, seismic excitation, and phase plane analysis are considered. Simple multi-degree-of-freedom systems are analyzed. Energy concepts and the Rayleigh method are applied to lumped and distributed systems. Elementary rotor dynamics are also considered.

A section containing practice problems keyed to the chapters follows the last chapter; the answers are given. An index concludes the book.

There is always the danger that a textbook proportioning to cover such a wide range of topics will do none of them, or its readers, justice. For the most part the author has successfully avoided this trap. To my personal taste chapters 5 and 9 which deal with dynamics and chapter 8 on automatic control are a bit lean. I would have preferred a stronger treatment and more applications. Another reviewer might say the same about other sections.

Considering the intended usage, and the latitude given the instructor to introduce additional material, the author has produced a reasonable compromise.

The text is well illustrated with clearly marked line drawings. The typeset and organization are pleasing to the eye. The style and exposition are easy to read. Students will probably be pleased with the quantity of well-written descriptive material, which is generally more voluminous than is found in American technical books.

H.J. Sneed  
Department of Mechanical Engineering,  
Aeronautical Engineering & Mechanics  
Rensselaer Polytechnic Institute  
Troy, New York

### DYNAMICS IN CIVIL ENGINEERING: ANALYSIS AND DESIGN

A. Major  
Akadémiai Könyvkiadó, Budapest, Hungary  
Vol. I-IV, 1981, 1212 pages, \$96.00

Vibration problems caused by time-dependent loads arise in many structures. This comprehensive reference book deals with the theoretical and practical aspects of solving such dynamic problems, which are often very complex. This book is a completely revised and considerably enlarged edition of the internationally known author's 1961 work, Vibration Analysis and Design of Foundations for Machines and Turbines, which is a standard reference book for many engineers.

The extended scope of this second edition includes more detailed treatment of the fundamentals of structural dynamics and their practical applications. To assure convenient handling of this increased material, the book has been divided into four volumes. The fourth volume is devoted to wind and earthquake effects on tall buildings and various industrial structures and the dynamics of bridges.

The first volume (320 pp) contains a condensed but up-to-date introduction to structural and soil dynamics. In addition, the reader is exposed to the fundamental principles governing the design of machine foundations. The second volume (302 pp) deals with the vibratory characteristics of such machines as hammers and reciprocating engines and with the design of their foundations, including vibration isolation and mechanical methods for mitigating undesirable vibration effects.

The third volume (291 pp), a continuation of the subject matter of volume two, deals with high-speed machinery and steam and nuclear power plants. Again, such general considerations as design criteria are followed by descriptions of various computational methods and useful structural details of machine foundations.

The last volume (306 pp) is devoted mostly to vibrations of tall buildings and industrial structures subjected to wind, earthquake, and blast loads. One chapter deals with the dynamics of hydraulic structures. Finally, the reader is introduced to various types of bridge vibration.

The reviewer believes that the four volumes contain a most comprehensive treatment of dynamic problems in civil engineering from a wide variety of fields. Clear presentation of basic theories is followed by practical applications. In addition, a vast amount of pertinent information is given in tables and graphs; such information is not otherwise easily available to the practicing engineer. Application of the various computational methods are illustrated by numerical examples, and the work of the designer is facilitated by numerous figures showing structural details. The author also provides an extensive bibliography, citing 1377 references. The book is well produced, edited, and indexed. The reviewer believes that these volumes represent a significant contribution to the literature of structural dynamics and will become a standard reference book for anyone interested in the dynamic analysis and design of structures.

R. Szilard  
University of Dortmund  
August-Schmidt-Strasse  
4600 Dortmund 50 (Eichlinghofen)

## BOOK REVIEWS: 1981

Ariman, T., Liu, S.C., and Nickell, R.E., eds., Lifeline Earthquake Engineering - Buried Pipelines, Seismic Risk and Instrumentation, ASME Special Publ. PVP-34, New York, NY, 1979; Reviewed by L.R.L. Wang, SVD, 13 (3), p 23 (Mar 1981)

Barr, D.F. and Miller, R.K., Basic Industrial Hearing Conservation, Fairmont Press, Atlanta, GA, 1979; Reviewed by R.J. Peppin, SVD, 13 (9), pp 37-38 (Sept 1981)

Bendat, J.S. and Piersol, A.G., Engineering Applications of Correlation and Spectral Analysis, John Wiley and Sons, New York, NY, 1980; Reviewed by H. Saunders, SVD, 13 (11), pp 25-26 (Nov 1981)

Bennett, S.E., Ross, A.L., and Zemanick, P.Z., eds., Failure Prevention and Reliability, ASME, New York, NY, 1977; Reviewed by H. Saunders, SVD, 13 (1), p 30 (Jan 1981)

Blekhman, I.I., ed., Nonlinear Vibration of Mechanical Systems, Volume 2 of Vibratsii v Tekhnike (Engineering Vibration), Chelomei, V.N., ed., Mashinostroenie, Moscow, 1979 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), p 25 (Mar 1981)

Bolotin, V.V., ed., Vibration of Linear Systems, Volume 1 of Vibratsii v Tekhnike (Engineering Vibration), Chelomei, V.N., ed., Mashinostroenie, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (3), pp 24-25 (Mar 1981)

Bolotin, V.V., Sluchainye Kolebaniya Uprugikh Sistem (Random Vibration of Elastic Systems), Nauka, Glavnaya Redaktsiya Fiziko-matematicheskoi Literatury, Moscow, 1978 (in Russian); Reviewed by M. Dublin, SVD, 13 (7), p 15 (July 1981)

Buzdugan, G., Mihailescu, E., and Rades, M., Vibration Measurement, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibanez, SVD, 13 (1), pp 31-32 (Jan 1981)

Carneiro, F.L.L.B., Ferrante, A.J., and Brebbia, C.A., eds., Offshore Structures Engineering, Gulf Publishing Co., Houston, TX, 1979; Reviewed by K.E. McKee, SVD, 13 (4), p 29 (Apr 1981)

Chen, S.S. and Bernstein, M.D., eds., Flow Induced Vibrations, ASME, New York, NY, 1979; Reviewed by D.W. Sallet, SVD, 13 (6), pp 19-21 (June 1981)

Clarkson, B.L., ed., Stochastic Problems in Dynamics, Fearon-Pitman Publ., Belmont, California; Reviewed by H. Saunders, SVD, 13 (4), pp 29-30 (Apr 1981)

Close, C.M. and Frederick, D.K., Modeling and Analysis of Dynamic Systems, Houghton Mifflin Co., Boston, MA, 1978; Reviewed by J.M. Prentis, SVD, 13 (9), pp 36-37 (Sept 1981)

Decker, K.-H., Maschinenelemente, Gestaltung und Berechnung, 7th Edition, Carl Hauser Vg., München, Fed. Rep. Germany, 1975 (in German); Reviewed by G. Schweitzer, SVD, 13 (2), pp 21-22 (Feb 1981)

Edelen, D.G.B., Lagrangian Mechanics of Nonconservative Nonholonomic Systems, Noordhoff International Publishing, Leyden, The Netherlands, 1977; Reviewed by H.K. Sachs, SVD, 13 (1), p 31 (Jan 1981)

Irons, B. and Ahmad, S., Techniques of Finite Elements, John Wiley and Sons, Somerset, NJ, 1980; Reviewed by A.J. Kalinowski, SVD, 13 (10), pp 37-38 (Oct 1981)

Kawata, K. and Jumpei, S., eds., High Velocity Deformation of Solids, Springer-Verlag, Berlin, 1978; Reviewed by S.E. Benzley, SVD, 13 (2), p 21 (Feb 1981)

Kuttruff, H., Room Acoustics, Applied Science Publishers, Ltd., London, UK, 2nd Edition, 1979; Reviewed by D.M. Yeager, SVD, 13 (11), pp 23-24 (Nov 1981)

Lalanne, M., Berthier, P., and Der Hagopian, J., Mécanique Des Vibrations Linéaires, Masson Publ., Paris, France, 1980 (in French); Reviewed by F.C. Nelson, SVD, 13 (8), pp 30-31 (Aug 1981)

Lyons, R.H., Statistical Energy Analysis of Dynamic Systems, MIT Press, Cambridge, MA; Reviewed by H. Saunders, SVD, 13 (12), pp 27-28 (Dec 1981)

Mader, C.L., Numerical Modeling of Detonations, University of California Press, Berkeley, CA, 1979; Reviewed by J.J. Dick, SVD, 13 (6), pp 18-19 (June 1981)

Magrab, E.B., Vibrations of Elastic Structural Members, Sijthoff & Noordhoff, Alphen aan den Rijn, The Netherlands, 1979; Reviewed by K.E. McKee, SVD, 13 (4), pp 30-31 (Apr 1981)

Main, I.G., Vibrations and Waves in Physics, Cambridge University Press, New Rochelle, NY, 1978; Reviewed by A.J. Kalinowski, SVD, 13 (11), pp 24-25 (Nov 1981)

Major, A., Dynamics in Civil Engineering: Analysis and Design, Akadémiai Könyvkiadó, Budapest, Hungary, Vol. I-IV, 1981; Reviewed by R. Szilard, SVD, 13 (12), p 29 (Dec 1981)

Nayfeh, A.H. and Mook, D.T., Nonlinear Oscillations, John Wiley and Sons, New York, NY, 1979; Reviewed by R.A. Ibrahim, SVD, 13 (5), pp 31-32 (May 1981)

Oden, J.T. and Reddy, J.N., Variational Methods in Theoretical Mechanics, Springer-Verlag, Vienna and New York, 1976; Reviewed by H. Saunders, SVD, 13 (10), p 39 (Oct 1981)

Otnes, R.K. and Enochson, L., Applied Time Series Analysis - Volume 1. Basic Techniques, John Wiley and Sons, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (9), pp 38-40 (Sept 1981)

Paul, B., Kinematics and Dynamics of Planar Machinery, Prentice Hall, Inc., Englewood Cliffs, NJ, 1979; Reviewed by H. Saunders, SVD, 13 (8), pp 29-30 (Aug 1981)

Paz, M., Structural Dynamics Theory and Computation, Van Nostrand Reinhold Co., New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), p 30 (May 1981)

Perrone, N. and Pilkey, W., eds., Structural Mechanics Software Series, Volume III, University Press of Virginia, Charlottesville, VA, 1980. Reviewed by M.M. Hurwitz, SVD, 13 (6), p 19 (June 1981)

Phillips, O.M., The Dynamics of the Upper Ocean, Cambridge University Press, New Rochelle, NY, 2nd Edition, 1977; Reviewed by J.R. Breton, SVD, 13 (10), p 37 (Oct 1981)

Pipes, R.B., ed., Nondestructive Evaluation and Flaw Criticality for Composite Materials, American Society for Testing and Materials (STP 696), Philadelphia, PA, 1979; Reviewed by S.E. Benzley, SVD, 13 (8), p 30 (Aug 1981)

Prentis, J.M., Dynamics of Mechanical Systems, Halsted Press, New York, NY, 2nd Edition, 1980; Reviewed by H.J. Sneed, SVD, 13 (12), pp 28-29 (Dec 1981)

Rades, M., Identification of Vibrating Systems, Rumanian Socialist Republic Academic Press, 1979 (in Rumanian); Reviewed by P. Ibáñez, SVD, 13 (2), pp 22-23 (Feb 1981)

Rosenberg, R.M., Analytical Dynamics of Discrete Systems, Plenum Press, New York, NY, 1977; Reviewed by R.A. Scott, SVD, 13 (3), pp 22-23 (Mar 1981)

Simiu, E. and Scanlan, R.H., Wind Effects on Structures, John Wiley and Sons, New York, NY, 1980; Reviewed by K.E. McKee, SVD, 13 (5), pp 30-31 (May 1981)

Taplin, D.M.R., Advances in Research on the Strength of Metals, Volume 2B - Fatigue, Pergamon Press, New York, NY, 1978; Reviewed by H. Saunders, SVD, 13 (7), pp 15-16 (July 1981)

Tominari, N., Seto, K., and Okada, J., Analysis and Design of Servo Control Systems, Corona Publishing Co., Ltd., Tokyo, Japan, 1979 (in Japanese); Reviewed by T. Iwatsubo, SVD, 13 (7), pp 16-17 (July 1981)

# SHORT COURSES

## JANUARY

### PROBABILISTIC AND STATISTICAL METHODS IN MECHANICAL AND STRUCTURAL DESIGN

Dates: January 11-15, 1982  
Place: Tucson, Arizona  
Objective: The objective of this short course and workshop is to review the elements of probability and statistics and the recent theoretical and practical developments in the application of probability theory and statistics to engineering design. Special emphasis will be given to fatigue and fracture reliability.

Contact: Special Professional Education, Harvill Building No. 76, Room 237, College of Engineering, The University of Arizona, Tucson, AZ 85721 - (602) 626-3054.

### MACHINERY VIBRATION ANALYSIS

Dates: January 26-29, 1982  
Place: Tampa, Florida  
Objective: In this four-day course on practical machinery vibration analysis, savings in production losses and equipment costs through vibration analysis and correction will be stressed. Techniques will be reviewed along with examples and case histories to illustrate their use. Demonstrations of measurement and analysis equipment will be conducted during the course. The course will include lectures on test equipment selection and use, vibration measurement and analysis including the latest information on spectral analysis, balancing, alignment, isolation, and damping. Plant predictive maintenance programs, monitoring equipment and programs, and equipment evaluation are topics included. Specific components and equipment covered in the lectures include gears, bearings (fluid film and antifriction), shafts, couplings, motors, turbines, engines, pumps, compressors, fluid drives, gearboxes, and slow speed paper rolls.

Contact: Dr. Ronald L. Eshleman, The Vibration Institute, 101 West 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

## FEBRUARY

### VIBRATION AND SHOCK SURVIVABILITY, TESTING, MEASUREMENT, ANALYSIS, AND CALIBRATION

Dates: February 1-5, 1982  
Place: Santa Barbara, California  
Dates: March 1-5, 1982  
Place: College Park, Maryland  
Dates: April 12-16, 1982  
Place: Dayton, Ohio  
Dates: July 19-23, 1982  
Place: England  
Objective: Topics to be covered are resonance and fragility phenomena, and environmental vibration and shock measurement and analysis; also vibration and shock environmental testing to prove survivability. This course will concentrate upon equipments and techniques, rather than upon mathematics and theory.

Contact: Wayne Tustin, 22 East Los Olivos St., Santa Barbara, CA 93105 - (815) 682-7171.

### VIBRATION TESTING AND SIGNAL ANALYSIS

Dates: February 16-18, 1982  
Place: Southampton, England  
Objective: Topics include: types of testing, introduction to the various types of signal-linear system theory, etc. (i) testing with applied excitation - techniques - steady state, slow sweep, transient, random, (ii) response analysis (only) - system in motion due to natural excitation; instrumentation and signal conditioning - effects of attachments on system characteristics; instrumentation system characteristics: limitations, e.g. bandwidth, integration, analogue filtering, etc; signal processing; and specification testing.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, SO9 5NH - (0703) 559122, Ext. 2310.

### BALANCING OF ROTATING MACHINERY

Dates: February 23-26, 1982  
Place: Galveston, Texas

**Objective:** The seminar will emphasize the practical aspects of balancing in the shop and in the field. The instrumentation, techniques, and equipment pertinent to balancing will be elaborated with case histories. Demonstrations of techniques with appropriate instrumentation and equipment are scheduled. Specific topics include: basic balancing techniques (one- and two-plane), field balancing, balancing without phase measurement, balancing machines, use of programmable calculators, balancing sensitivity, flexible rotor balancing, and effect of residual shaft bow on unbalance.

Contact: Dr. Ronald L. Eshleman, Vibration Institute, 101 W. 55th St., Suite 206, Clarendon Hills, IL 60514 - (312) 654-2254.

## MARCH

### MEASUREMENT SYSTEMS ENGINEERING

Dates: March 1-5, 1982

Place: Phoenix, Arizona

### MEASUREMENT SYSTEMS DYNAMICS

Dates: March 8-12, 1982

Place: Phoenix, Arizona

**Objective:** Program emphasis is on how to increase productivity, cost-effectiveness of data acquisition systems and groups in the field and in the laboratory. Emphasis is also on electrical measurements of mechanical and thermal quantities.

Contact: Peter K. Stein, 5602 East Monte Rosa, Phoenix, AZ 85018 - (602) 945-4603/946-7333.

### SHOCK AND VIBRATION CONTROL

Dates: March 16-18, 1982

Place: Southampton, England

**Objective:** Topics include: introduction - structural parameters and their role in vibration control; dynam-

ic properties of structural materials - damping materials and their properties, application of damping treatments to structures, fibre reinforced plastics, fatigue; mobility methods - concepts, system coupling, application to the isolation problem, approximate methods; vibration transmission through structures - path identification - classical, cross correlation, etc., power flow - mechanisms, use of statistical energy methods, acoustic radiation, radiation efficiency; shock - impacts in machines - effects of structural parameters on acoustic radiation, isolation - machinery installations, the transient environment - packaging and packaging materials.

Contact: Mrs. G. Hyde, ISVR Conference Secretary, The University, Southampton, SO9 5NH - (0703) 559122, Ext. 2310.

## APRIL

### DESIGN OF FIXED OFFSHORE PLATFORMS

Dates: April 5-16, 1982

Place: Austin, Texas

**Objective:** This course is dedicated to the professional development of those engineers, scientists, and technologists who are and will be designing fixed offshore platforms to function in the ocean environment from the present into the twenty-first century. The overall objective is to provide participants with an understanding of the design and construction of fixed platforms, specifically the theory and processes of such design and the use of current, applicable engineering methods.

Contact: Continuing Engineering Studies, College of Engineering, Ernest Cockrell Hall 2.102, The University of Texas at Austin, Austin, TX 78712 - (512) 471-3506.

# NEWS BRIEFS:

news on current  
and Future Shock and  
Vibration activities and events

## COMPILATION OF DAMPING DESIGN GUIDE

The Flight Dynamics Laboratory, one of the Air Force Wright Aeronautical Laboratories located at Wright-Patterson Air Force Base Ohio, awarded a three-year contract in September 1981 to Lockheed-California Company, Burbank, California and University of Dayton Research Institute, Dayton, Ohio, to develop an aerospace structures technology damping design guide. The objective of this effort is to collect and summarize available design methods and data on acoustic and vibration control using damping materials/methodology and compile this information into a damping design guide which may be readily applied for use in controlling structure and equipment vibration problems on board aircraft, spacecraft, and other aerospace systems. The design guide will be written for aerospace systems designers and provide to the designer the methods of damping design, limits of application, sources of derivation, and examples illustrating the use of each method.

The scientific/engineering community is invited to offer examples of successful application of damping methods/technology and detailed background information for these examples for inclusion in the damping design guide. Data on available damping material adhesives and compounds are also of interest and will be included in the guide, as will a list of vendors active in this field.

Anyone interested in participating or offering information is urged to contact: J. Soovere, Lockheed-California Company, Dept 63G, Plant A-1, Burbank, California 91520 - (213) 847-2225; M. Drake, University of Dayton Research Institute, Dayton, Ohio 45469 - (513) 229-2644; or V. Miller, Flight Dynamics Laboratory, AFWAL/FIBED, Wright-Patterson Air Force Base Ohio 45433 - (513) 255-5229/5753.

## ERRATA

The following errors were noted in the article *Linear Dynamic Thermoelasticity - A Survey*, published in the September issue of the Digest.

"The head conduction equation," page 4, should read "The heat conduction equation."

"The functions  $\rho, \lambda, \dots$ ," page 4, should read "The parameters  $\rho, \lambda, \dots$ ."

"The function  $\theta_0$  in equation (3) . . .", page 5, should read "The parameter  $\theta_0$  in equation (3) . . ."

# INFORMATION RESOURCES

## THE METAL MATRIX COMPOSITES INFORMATION ANALYSIS CENTER

### MISSION

The MMCIAC, established in October 1980, is one of the newest of the DoD information analysis centers (IACs) administered and funded by the Defense Logistics Agency (DLA) and the Defense Technical Information Center (DTIC). As with the other IACs, the MMCIAC receives its technical sponsorship and guidance from a DoD laboratory, in this case the U.S. Naval Surface Weapons Center at Silver Spring, Maryland. Kaman Temp (a division of Kaman Sciences Corporation) located in Santa Barbara, California, operates and manages the MMCIAC.

The broad mission of the MMCIAC is to provide scientific and technical information analysis service to the DoD, other government agencies, government contractors, and the private sector in the area of metal matrix composite materials.

### MMC TECHNOLOGY PROGRAM

Throughout the past decade the DoD has manifested a strong interest in developing Metal Matrix Composite (MMC) materials and has invested an estimated 70 million dollars in this technology over the past ten years. In the late 1970s a MMC "thrust" was implemented to further accelerate the developmental pace. The results of recent efforts directed by the Army, Navy, Air Force, and Defense Advanced Research Projects Agency (DARPA) has advanced the MMC community rapidly toward systems applications. Present efforts focus on making this new technology more cost effective.

The MMC technology program, over the past 12 years, however, has resulted in a growing, but fragmented data base. Current programs are producing a large amount of technical data and information that, within a short time, will equal and possibly surpass all the data previously generated. Therefore,

a need exists to centrally accumulate, evaluate, analyze, and disseminate this technical data and information through a well developed and dedicated technology transfer program. The DoD Metal Matrix Composites Information Analysis Center was established as the basic element of such a program.

### TECHNICAL SCOPE

The subject matter coverage of the MMCIAC is the technology related to metal matrix composite materials. The materials are understood to be those composites that perform acceptably under severe conditions, both environmental and operational. The materials are those characterized as having high specific properties, proven environmental fatigue capability, reduced requirement for critical metals, improved creep and wear resistance, high design flexibility, high damage tolerance, and unique combinations of properties including mechanical, electrical, and thermal. The scope of this coverage embraces:

- Continuous fibers, wires, discontinuous whiskers with L/D 10, directionally solidified eutectics
- Fibers -- boron, graphite, silicon carbide, borsic, nitride, alumina, boron carbide, titanium diboride
- Wires -- stainless steel, tungsten, molybdenum, beryllium, titanium, niobium alloys and compounds
- Whiskers -- alumina, silicon carbide, silicon nitride
- MMC Systems -- alumina/magnesium, beryllium/titanium, boron/stainless steel/aluminum, boron/titanium/aluminum, borsic/aluminum, borsic/titanium, copper/graphite, graphite/lead, graphite/aluminum, tungsten/nickel.

Technical areas of interest for the MMCIAC include: manufacturing, fabrication process development,

defense systems applications, performance computations, cost, test and evaluation techniques and methods, properties data, operational serviceability and repair, environmental protection, sources, suppliers, and other MMC-related areas.

### **MMC PROPERTIES DATA BASE**

A special function of the Center is to establish and maintain an MMC properties data base from which to develop information useful to designers concerned with MMC applications. Documents acquired by the Center may contain or reference MMC test data that substantiate derived conclusions and/or analytical results. In these instances, supporting test data are examined and screened for potential MMCIAC data base incorporation. Properties and test data selected for incorporation are evaluated, formatted and placed into an MMC data base organized for selective retrieval and analysis. The data summaries or data books produced from the MMC data base will be disseminated periodically to the Center's users.

### **INFORMATION OPERATIONS**

The MMCIAC provides the facilities and capabilities to: (1) identify, collect, process, store, and disseminate authoritative MMC information; (2) prepare or sponsor the preparation of the necessary products and services to communicate this information to researchers, practicing specialists, manufacturers, and other users with interests and concerns in metal matrix composites; and (3) coordinate and augment existing information activities to improve the transmittal of this information to interested organizations and individuals in the government, military, and private sector.

Center activities include the collection, review, evaluation, analysis, dissemination of the literature related to MMC materials, and assisting visitors in using data files. Emphasis is placed on screening, filtering, and selective reduction to maintain a data base that truly reflects the current state-of-knowledge. MMCIAC personnel continuously review, analyze, refine, and pool worldwide published and unpublished scientific and technical information acquired from the DoD and NTIS and recognized professionals in Government and contractor organizations. They also moni-

tor publications of other IACs and data centers and actively participate in MMC technical conferences and symposia such as the MMC Technology Conference.

The Center's information sources include: Technical reports from DoD, other Government agencies, industry, and academic institutions, etc; open literature including foreign sources; unpublished papers; meetings; technical journals; conferences; workshops; and consultations with key scientists in the MMC community.

### **PRODUCTS AND SERVICES**

The MMCIAC provides a central, authoritative, and easily accessible body of information consistent with MMC materials development and applications. Specifically, it is designed to provide:

- Continuous and comprehensive information acquisition and compilation
- On call, specialized user services for answering technical and bibliographic inquiries from qualified individuals and organizations
- State-of-the-art studies of MMC technology with usefulness extending from the bench level to all levels of RDT&E management
- Scientific and engineering reference works such as handbooks, design manuals and periodic MMC materials properties data summaries
- Critical reviews and assessments of MMC technology and related subjects of significant interest to the Defense RDT&E community
- Current awareness and other user-oriented publications in a quarterly newsletter, notices and proceedings of MMC and related conferences, and announcements with bibliographical accounts of newly acquired information. The quarterly newsletter is available without charge to any interested individual or company engaged in materials research, development, testing, fabrication, and/or applications.

### **ORGANIZATION AND STAFF**

#### **Technical Monitor**

U.S. Naval Surface Weapons Center  
ATTN: Code R32/Dr. Steven G. Fishman  
White Oak Laboratory

Silver Spring, Maryland 20910  
(202) 394-2724

**Operator**

Kaman Tempo (Formerly General Electric-Tempo)  
816 State Street  
P.O. Drawer QQ  
Santa Barbara, California 93102  
(805) 963-6497

**Manager**

Louis A. Gonzalez  
Manager - Center Operations  
(805) 963-6497

**Service Points of Contact**

Jacques E. Schoutens  
Manager - Data Analysis  
(805) 963-6462

William E. Rogers  
Manager - Information Services  
(805) 963-6482

# ABSTRACT CATEGORIES

## MECHANICAL SYSTEMS

- Rotating Machines
- Reciprocating Machines
- Power Transmission Systems
- Metal Working and Forming
- Isolation and Absorption
- Electromechanical Systems
- Optical Systems
- Materials Handling Equipment

- Blades
- Bearings
- Belts
- Gears
- Clutches
- Couplings
- Fasteners
- Linkages
- Valves
- Seals
- Cams

Vibration Excitation  
Thermal Excitation

## STRUCTURAL SYSTEMS

- Bridges
- Buildings
- Towers
- Foundations
- Underground Structures
- Harbors and Dams
- Roads and Tracks
- Construction Equipment
- Pressure Vessels
- Power Plants
- Off-shore Structures

## STRUCTURAL COMPONENTS

- Strings and Ropes
- Cables
- Bars and Rods
- Beams
- Cylinders
- Columns
- Frames and Arches
- Membranes, Films, and Webs
- Panels
- Plates
- Shells
- Rings
- Pipes and Tubes
- Ducts
- Building Components

## EXPERIMENTATION

Measurement and Analysis  
Dynamic Tests  
Scaling and Modeling  
Diagnostics  
Balancing  
Monitoring

## VEHICLE SYSTEMS

- Ground Vehicles
- Ships
- Aircraft
- Missiles and Spacecraft

## ELECTRIC COMPONENTS

- Controls (Switches, Circuit Breakers)
- Motors
- Generators
- Transformers
- Relays
- Electronic Components

## ANALYSIS AND DESIGN

Analogs and Analog Computation  
Analytical Methods  
Modeling Techniques  
Nonlinear Analysis  
Numerical Methods  
Statistical Methods  
Parameter Identification  
Mobility/Impedance Methods  
Optimization Techniques  
Design Techniques  
Computer Programs

## BIOLOGICAL SYSTEMS

- Human
- Animal

## MECHANICAL COMPONENTS

- Absorbers and Isolators
- Springs
- Tires and Wheels

## DYNAMIC ENVIRONMENT

- Acoustic Excitation
- Shock Excitation

## GENERAL TOPICS

Conference Proceedings  
Tutorials and Reviews  
Criteria, Standards, and Specifications  
Bibliographies  
Useful Applications

# ABSTRACTS FROM THE CURRENT LITERATURE

Copies of articles abstracted in the DIGEST are not available from the SVIC or the Vibration Institute (except those generated by either organization). Inquiries should be directed to library resources. Government reports can be obtained from the National Technical Information Service, Springfield, VA 22151, by citing the AD-, PB-, or N- number. Doctoral dissertations are available from University Microfilms (UM), 313 N. Fir St., Ann Arbor, MI; U.S. Patents from the Commissioner of Patents, Washington, D.C. 20231. Addresses following the authors' names in the citation refer only to the first author. The list of periodicals scanned by this journal is printed in issues 1, 6, and 12.

## ABSTRACT CONTENTS

<b>MECHANICAL SYSTEMS . . . . .</b>	<b>41</b>	Gears . . . . .	61	<b>MECHANICAL PROPERTIES . . . . .</b>	<b>72</b>
Rotating Machines . . . . .	41	Couplings . . . . .	61	Damping . . . . .	72
Reciprocating Machines . . . . .	48	Fasteners . . . . .	61	Fatigue . . . . .	73
Metal Working and Forming . . . . .	48	Linkages . . . . .	62		
		Valves . . . . .	62		
		Seals . . . . .	62		
<b>STRUCTURAL SYSTEMS . . . . .</b>	<b>48</b>	<b>STRUCTURAL COMPONENTS . . . . .</b>	<b>63</b>	<b>EXPERIMENTATION . . . . .</b>	<b>75</b>
Buildings . . . . .	48	Bars and Rods . . . . .	63	Measurement and Analysis . . . . .	75
Towers . . . . .	49	Beams . . . . .	64	Dynamic Tests . . . . .	76
Foundations . . . . .	49	Cylinders . . . . .	64	Diagnostics . . . . .	77
Underground Structures . . . . .	49	Frames and Arches . . . . .	64	Balancing . . . . .	79
Harbors and Dams . . . . .	50	Panels . . . . .	65	Monitoring . . . . .	81
Construction Equipment . . . . .	50	Plates . . . . .	65		
Power Plants . . . . .	51	Shells . . . . .	66	<b>ANALYSIS AND DESIGN . . . . .</b>	<b>81</b>
Off-shore Structures . . . . .	52	Pipes and Tubes . . . . .	68	Analytical Methods . . . . .	81
<b>VEHICLE SYSTEMS . . . . .</b>	<b>52</b>	Ducts . . . . .	69	Modeling Techniques . . . . .	82
Ground Vehicles . . . . .	52	Building Components . . . . .	70	Numerical Methods . . . . .	82
Ships . . . . .	53	<b>ELECTRIC COMPONENTS . . . . .</b>	<b>70</b>	Statistical Methods . . . . .	82
Aircraft . . . . .	53	Generators . . . . .	70	Parameter Identification . . . . .	83
Missiles and Spacecraft . . . . .	54			Design Techniques . . . . .	83
				Computer Programs . . . . .	83
<b>MECHANICAL COMPONENTS . . . . .</b>	<b>55</b>	<b>DYNAMIC ENVIRONMENT . . . . .</b>	<b>70</b>	<b>GENERAL TOPICS . . . . .</b>	<b>85</b>
Absorbers and Isolators . . . . .	55	Acoustic Excitation . . . . .	70	Conference Proceedings . . . . .	85
Blades . . . . .	56	Shock Excitation . . . . .	71	Tutorials and Reviews . . . . .	85
Bearings . . . . .	56	Vibration Excitation . . . . .	72	Criteria, Standards, and Specifications . . . . .	86

# MECHANICAL SYSTEMS

## ROTATING MACHINES

(Also see Nos. 2585, 2593, 2655, 2660, 2661, 2663, 2665, 2666, 2667, 2668, 2669, 2676, 2688)

### 81-2505

#### Recognition of the Causes of Rotor Vibration in Turbomachinery

D.M. Smith

Turbine Generator Div., Associated Electrical Industries, Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 1-4, 11 refs

**Key Words:** Rotors, Turbomachinery, Oil film bearings, Journal bearings, Vibration source identification

This paper discusses actions which influence rotor vibration and means of recognizing vibration set up by these actions. Attention is given primarily to rotors carried in oil-film journal bearings, as widely used in land and marine turbine plants. Stator vibration which contributes to rotor vibration is taken into account.

### 81-2506

#### Double-Frequency Accelerations in Turbogenerator Rotors Resulting from Anisotropy in the Bearings

W. Kellenberger

Brown Boveri, Birr, Switzerland, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 415-420, 5 figs, 3 tables

**Key Words:** Rotors, Turbogenerators, Acceleration effects, Bearings, Anisotropy

The motion of a turbogenerator rotor in any plane normal to the rotation axis is known to be elliptical. This results in alternating accelerations of all points of the shaft at double-rotation frequency. This paper is concerned with the calculation of these accelerations and the resulting alternating forces which act (at constant speed) on every rotor component (in addition to the steady centrifugal forces) and must be conveyed, over the component's attachment, to the main body of the rotor. Examples of attached

components are: slot-wedges, balancing masses, ventilator fan blades and end-rings.

### 81-2507

#### Further Investigations into Load Dependent Low Frequency Vibration of the High Pressure Rotor on Large Turbo-Generators

S.H. Greathead and M.D. Slocumbe

N.E. Region Scientific Services Dept., MIMechE, Otley Rd., Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 401-413, 15 figs, 2 tables, 6 refs

**Key Words:** Rotors, Turbogenerators, Nonsynchronous vibration, Low frequencies

This paper presents results from a gland rig which has been built to measure unbalanced steam forces arising in multi-cell shaft labyrinth glands with different geometries and flow conditions. Further operational evidence from observations and measurements on this type of machine obtained during investigations into this load dependent vibration instability is also presented. The gland rig results indicate that large unbalanced steam forces can be generated from steam flow in shaft glands. The operational evidence supports this and also indicates that such forces make an important contribution to the load dependent h.p. rotor instability problems experienced.

### 81-2508

#### On the Influence of Casing Stiffness in Turbomachinery Vibration Analysis

S.S. Stecco and M. Pinzauti

Dept. of Energetics, Univ. of Florence, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 139-144, 8 figs, 3 refs

**Key Words:** Turbomachinery, Critical speeds, Interaction: rotor-casing

Critical frequencies of turbomachines are often highly affected by the interaction effects between casing and rotor. A method, original under various aspects, is presented in order to predict from theoretical values (or, in some cases, from experimental data) the vibrational behavior of the machine. A practical application is also given showing the numerical results.

**81-2509****Modal Dynamic Simulation of Flexible Shafts in Hydrodynamic Bearings**

H.F. Black and R.D. Brown

Heriot-Watt Univ., Edinburgh, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 109-113, 6 figs, 13 refs

**Key Words:** Rotors, Flexible shafts, Modal analysis, Non-linear theories

The major sources of non-linearity in flexible rotors are the forces originating from hydrodynamic bearings. When large excitation forces occur, journal motion may be so great that nonlinearity must be considered. The calculation time for nonlinear simulation depends on the number of modes used and the lubricant film force model. An existing Rayleigh-Ritz linear program was adapted for numerical integration. Bearing oil films forces were obtained as time dependent functions using an approximate method. The results presented demonstrate that nonlinear effects can be significant for peak response levels.

**81-2510****The Transient Response of Turbo-Alternator Rotor Systems under Short-Circuiting Conditions**

J.S. Rao, D.K. Rao, and K.V. Bhaskara Sarma

Indian Inst. of Technology, New Delhi, India, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrg., pp 271-275, 4 figs, 1 table, 7 refs

**Key Words:** Rotors, Torsional vibration, Natural shapes, Transfer matrix method, Computer programs

Sudden short-circuiting conditions at the alternator end generate predominant transient torsional oscillations in a turbo-alternator rotor inducing severe dynamic stresses. To evaluate these stresses, a continuous transfer matrix model was developed to determine torsional frequencies and modes. A discrete dynamic system of specified number of rotors is extracted from continuous system and its modes are evaluated by Jacobian method. Transient response is evaluated by modal expansion method. A computer program was developed and the results for a 6MW turbo-alternator system are presented.

**81-2511****An Approximate Formula for the Fundamental Fre-****quency of a Uniform Rotating Beam Clamped off the Axis of Rotation**

D.H. Hodges

Aeromechanics Lab., U.S. Army Research and Technology Labs. (AVRADCOM), Ames Res. Ctr., Moffett Field, CA, J. Sound Vib., 77 (1), pp 11-18 (July 8, 1981) 5 tables, 8 refs

**Key Words:** Rotors, Blades, Beams, Rotating structures, Fundamental frequency

A semi-empirical method involving asymptotic expansions is used to obtain an approximate formula for the fundamental frequency of a uniform rotating beam clamped off the axis of rotation. Results from the formula are shown to be of the order of 0.1% different from the exact results for a wide range of rotor speeds and hub radii up to the order of blade length. Thus, the designer is provided with a rapid, very accurate estimate of the frequency, without having to interpolate results from a chart or run a digital computer program.

**81-2512****Finite Element Analysis of Rotating Disks**

G.L. Nigh and M.D. Olson

Dept. of Civil Engrg., Univ. of British Columbia, Vancouver, British Columbia, Canada, J. Sound Vib., 77 (1), pp 61-78 (July 8, 1981) 8 figs, 1 table, 16 refs

**Key Words:** Disks (shapes), Rotating structures, Finite element technique, Critical speeds, Viscous damping

A finite element formulation is presented for the analysis of rotating disks in either a body-fixed or a space-fixed co-ordinate system. The in-plane stress distribution resulting from the in-plane body force due to rotation is determined first by a plane stress finite element analysis. This stress distribution is then used in calculating the out-of-plane geometric stiffness which in turn is added to the linear bending stiffness. In the space-fixed co-ordinate system, inertia and a viscous type damping also contribute to the out-of-plane stiffness, even in the steady state case. The formulation presented here places no restrictions on the disk geometry if the problem is solved in a body-fixed co-ordinate system, although only disks of axisymmetric geometry may be considered in the space-fixed co-ordinate system. A direct method of determining the critical speeds through an eigenvalue analysis in space-fixed co-ordinates is presented. The undamped steady state response to a space-fixed transverse point load is then examined. The effects of a viscous type damping are also presented.

**81-2513****Reduction of Twice per Revolution Vibration Levels Due to Weight Effect in Large Turbogenerators**

N. Bachschmid and G. Diana

Milan Polytechnic, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 203-208, 11 figs, 2 tables, 10 refs

**Key Words:** Rotor, Turbogenerators, Vibration control, Stiffness coefficients, Asymmetry

A method is presented for determining the rotating stiffness unequality from the statical deflection as well as from the twice per revolution vibration measurements. In this way it is possible to verify if, and how strong, dynamical effects due to rotating speed may change the statical stiffness unequality distribution. It is further possible to detect where corrections must be applied in order to reduce the twice per revolution vibration levels. This method was applied to a 600 MW generator and proved to be reliable and a successful tool "twice per revolution balancing."

Politechnika Łódzka, Łódź, Poland, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 289-296, 15 figs, 5 refs

**Key Words:** Rotors, Supports, Parametric response, Stiffener effects

Analysis of instability regions and forced vibrations of parametric discrete/machine/subsystems, interacting with real/supporting/structures is given and applied to model machines with rotors of unequal principal stiffnesses. Laboratory test results are cited and compared with computed ones, regarding instability regions and types of instability, forced vibrations amplitudes and journal center loci. First four harmonics content was computed and plotted for full experimental speed range.

**81-2514****Relative Energy Concepts in Rotating System Dynamics**

G.T.S. Done

The City Univ., London, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 283-287, 5 figs, 4 refs

**Key Words:** Rotor, Work and energy balance

The concept of relative work and energy; i.e., work and energy expressed relative to nonfixed axes, is not a commonly used one, but it is nevertheless just as valid as that of relative displacement, velocity and acceleration. The basic mechanics are presented in the paper, and it is shown how problems that have arisen in classifying certain types of rotating systems as conservative or nonconservative are resolved. Both absolute and relative energy balances are formulated for two models that exhibit mechanical instability; namely, an unsymmetric cross-section rotating shaft and the lag-plane ("ground resonance") model of a helicopter rotor.

**81-2516****A Physical Explanation of Parametric Instabilities in Unsymmetric Rotors**

D.A. Peters and I. Zvolanek

Washington Univ., St. Louis, MO, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 77-82, 8 figs, 16 refs

**Key Words:** Rotor, Whirling, Flutter, Parametric excitation

Past work on instabilities in unsymmetric rotors has shown that instabilities can conceivably occur whenever the sum or difference of two natural frequencies equals an integer multiple of the rotor speed. It is also known that some of these potential instabilities are realized neither analytically nor experimentally. In this paper, rules are developed that predict which potential instabilities will occur in the presence of zero damping.

**81-2517****Instability Threshold of an Unbalanced, Rigid Rotor in Short Journal Bearings**

J.W. Lund and H.B. Nielsen

Dept. of Machine Elements, The Technical Univ. of Denmark, Denmark, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 91-95, 3 figs, 4 refs

**Key Words:** Rotors, Rigid rotors, Unbalanced mass response, Parametric excitation

The unbalance response of a rigid rotor in short journal bearings is considered. The whirl orbits are assumed to be elliptical at synchronous frequency and are determined from the method of averaging. The stability of the orbital motion is investigated on the basis of the variational equations which include the effect of parametric excitation. The calculated zones of instability are obtained as functions of the Sommerfeld number and a rotor mass parameter for several values of the mass unbalance. The results are shown in a diagram.

shafts is presented. Cracks occurred at circumferential notches cut in the shaft near shrunk-on discs. Fractography showed fatigue cracks initiated at these notches from pits developed under the action of cyclic bending in a wet stream/condensate environment. Favorable comparison between predicted growth rates and observed growth rates suggest that for this study, fracture mechanics represents a viable tool for turbine shaft design and failure analysis, at least during the crack growth stage. Results also indicate that once the crack is initiated, failure will occur in a matter of days so that corrosion fatigue crack nucleation and the growth of very small cracks dominates the failure process.

### 81-2518

#### Acceleration of Unbalanced Rotor through the Resonance of Supporting Structure

F. Victor and F. Ellyin

Dept. of Civil Engrg., Univ. of Sherbrooke, Sherbrooke, Quebec, Canada, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 419-424 (June 1981) 11 figs, 10 refs

**Key Words:** Rotors, Unbalanced mass response, Resonance pass through, Transverse shear deformation effects, Rotatory inertia effects, Internal damping, Viscous damping

The dynamic response of a simple beam excited at its mid-span by the action of a turbomachine secured to it, is investigated in detail. The forcing function includes transients at startup or shutdown. Effects of the shear deformation, rotatory inertia, and the internal viscous damping, which may depend on the frequency, are considered individually as well as in combined forms. The results indicate that the maximum amplitude of vibration is highly dependent on the acceleration rate through the critical frequency. There is also an apparent shift in its position as compared to the classical resonance frequency. Influences of shear deformation and rotatory inertia are significant when the supporting structure (or foundation) is relatively massive.

### 81-2520

#### A Method of Calculating the Vibrational Behaviour of Coupled Rotating Shafts Containing a Transverse Crack

I.W. Mayes and W.G.R. Davies

Central Electricity Generating Board, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 17-27, 9 figs, 9 refs

**Key Words:** Shafts, Cracked media

A method of calculating the vibrational response of a coupled rotor system to a transverse crack using standard finite-element computer programs is briefly described. The method employs the technique of successive approximations and utilizes the fact that the fractional change in stiffness of a rotor is small even for large cracks and that for speeds away from critical speeds of the shaft, the crack opening and closing is dominated by self-weight bending. The method has been validated by comparing calculations with the experimental results from a four-bearing, two-shaft spin rig, one of whose shafts has a propagating transverse crack. The application of the method to two suspect turbo-generators is described.

### 81-2519

#### Fatigue and Fracture Analysis of Two Turbine Shafts

B.N. Leis, K. Dufrane, R. Rungta, R.D. Buchheit, M. Tuttle, P. Skulte, and S. Collard  
Battelle Columbus Lab., Columbus, OH, ASME Paper No. 81-PVP-27

**Key Words:** Shafts, Fatigue life, Crack propagation

A coupled fractographic and mechanics based analysis of radical cracking problems in two low pressure steam turbine

### 81-2521

#### On the Occurrence of Unstable Vibrations of a Shaft Having Either Asymmetrical Stiffness or Asymmetrical Rotor, Supported by Asymmetrically Flexible Pedestals

H. Ota and K. Mizutani

Dept. of Mech. Engrg., Faculty of Engrg., Nagoya Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 181-186, 6 figs, 1 table, 8 refs

**Key Words:** Shafts, Rotors, Variable material properties, Vibration response

In a rotating shaft with unequal stiffness or with an asymmetrical rotor, two kinds of unstable vibrations occur. In this paper, the mechanisms which cause the occurrence of unstable vibrations are clearly explained. Conditions under which unstable vibrations occur are derived and ascertained by use of an analog computer.

The accuracy of rotordynamic calculations is governed by the quality of the available computer model, which for turbo-alternator plant includes three main elements: rotor, bearings and foundations. Existing rotor models are constructed from manufacturers' sectional data idealized empirically to include the stiffening effect of abrupt changes of diameter. A technique for measuring the natural frequencies and modal shapes of individual rotors is described. The measurements were originally intended for comparison with calculations but a method was later developed for calculating an effective stiffness profile from the measured modal shape which was then used to construct a new improved rotor model. Results of rotordynamic calculations from the existing and improved computer models are presented and compared with measured data. The technique has also been used successfully for locating the axial position of rotor cracks.

### 81-2522

#### Vibration of a Rotating Shaft Passing through Two Critical Speeds

S. Yanabe and A. Tamura

Tokyo Inst. of Technology, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 19-35, 6 figs, 2 tables, 11 refs

**Key Words:** Shafts, Critical speeds, Damping effects

The vibration of a rotating shaft which passes through two critical speeds successively under the condition of the uniform acceleration rate is analyzed theoretically taking account of the damping force. The exact solution and its approximate expressions of the nonstationary vibration are derived and their calculated results with respect to various values of the critical speed ratio  $n$  and the acceleration parameter  $\Omega_1$  are shown. Both results have a good agreement in a wide speed range including the maximum amplitude.

### 81-2523

#### A Technique for Modelling Rotors from Measured Vibration Characteristics

G.B. Thomas and P. Littlewood

Central Electricity Generating Board, Harrogate, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 445-451, 6 figs, 1 table, 9 refs

**Key Words:** Rotors, Mathematical models, Natural frequencies, Mode shapes, Measurement techniques, Stiffness coefficients

### 81-2524

#### A Contribution for the Calculations of Intermittent Vibrations of Electrically Driven Rotors

U. Hollenburg

Technische Universität, Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 339-346, 7 figs, 8 refs

**Key Words:** Motors, Rotors, Shafts, Amplitude analysis

During the planning of driving mechanisms, consisting of an electromotor, a coupling for the abutting shafts and a processing machine, it is necessary to assess the maximum ratings of the shafts produced by bending and torsional moments. Knowledge is required of the maximum amplitude during intermittent working conditions. Intermittent phenomena of motion of overcritical rotors appear mainly during the running-up since the bending (torsional critical speed) must be passed through until the nominal values are reached. In order to judge the vibrational behavior at the very beginning, the simultaneous consideration of the mechanical system and the electromagnetic process is indispensable. For the description of the various models, a symbolical rotor system is chosen from the many possible driving mechanisms. The continuous bending and torsional elastic shafts with circular cross sections are mounted orthotropically. These shafts are connected by a coupling which is assumed to be elastic. Mathematically, the problem is described by partial differential equations but the complete analytical solution is not obtainable. Thus the problem will be approximately solved by, first of all, determining the Eigenmode of the appointed conservative structure for a discretized finite element model. By means of a connected model transformation a set of ordinary nonlinear differential equations is obtained for which a numerical solution is possible.

**81-2525****Torsional Vibrations During the Starting Process in Driving Systems with Three Phase Motors**

H. Peeken, C. Troeder, and G. Diekhans

Inst. of Machine Elements and Machine Design, Technical Univ. Aachen, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 427-435, 16 figs, 2 tables, 3 refs

**Key Words:** Motors, Torsional vibration, Shafts, Drive shafts, Rotating machinery

Induction and synchronous machines produce an oscillation torque on starting which causes strong torsional excitation in connected machinery. A method to measure the air gap torques of the machines in driving systems is presented. With the help of a mathematical model of the machines, it is possible to calculate by digital simulation the torsional response in shaft systems considering that electrical and mechanical system are coupled. Parameter variations in the mechanical system show the dominant effects influencing the air gap torque produced during starting.

**81-2526****Investigation of a D.C. Motor Vibration Problem**

D. France and H. Grainger

Dynamics Section, Weir Pumps Ltd., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 83-90, 9 figs, 2 refs

**Key Words:** Motors, Vibration source identification, Resonant frequencies, Mountings, Elastomers

A severe vibration problem was experienced with a D.C. motor used to provide the drive for a paper making machine. The vibration frequency was found to be at the rotor slot number multiplied by rotational speed and distinct resonant regions were evident within the motor operating speed range. The paper describes the various steps taken to identify the excitation source and determine the characteristics of the resonant modes of vibration. Various solutions to the problem were considered and are described. The final solution was achieved by use of an elastomeric mounting arrangement for the motor bearings.

**81-2527****Computation of Vibrations of the Coupled System Machine-Foundation****E. Krämer**

Technische Hochschule Darmstadt, German Federal Republic, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 333-338, 10 figs, 2 tables

**Key Words:** Interaction: rotor-foundation, Journal bearings, Rotors, Foundations, Stiffener effects, Vibration response

A procedure is given for computing the unbalance vibrations of rotor-foundation systems. First the foundation is calculated separately. Its influence on the rotor system is represented by its dynamic stiffness at the connecting points to the rotor. With this the expense for computation is reduced to an acceptable level. According to some studies, in many cases it may be possible to assume the foundation as a rigid supporting base.

**81-2528****Vibration Analysis of Large Rotor-Bearing-Foundation-Systems Using a Model Condensation for the Reduction of Unknowns**

M. Jäcker

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 195-202, 10 figs, 4 refs

**Key Words:** Rotors, Interaction: rotor-foundation

For the dynamic analysis of many rotating structures it is necessary to take into account the dynamic behavior of their foundations. The high analysis costs due to the known complexity of the system can considerably be reduced by a reduction of the unknowns which is based on the speed-independent modal properties of the system components (model condensation, component mode method). The technique is applied to different linear dynamic problems (stationary and transient response, critical speeds, stability) in a consistent manner. Numerical examples are given for the stationary response problem.

**81-2529****Defining the Machine/Foundation Interface**

P.E. Simmons

Petrochemical Div., ICI Ltd., Wilton, Middlesbrough, Cleveland, OH, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge,

UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 5-8, 5 figs, 1 ref

**Key Words:** Interaction: rotor-foundation, Rotors, Foundations

As turbo-machines get larger their dynamic behavior is increasingly affected by the flexibility of their bearings, support structures and foundations. Also larger machines tend to require taller and generally more flexible foundations which are inadequately represented in the machine designer's mathematical model. There is a need for a system which adequately defines the interface and quantifies those characteristics of the foundations which are important to the machine designer. The purpose of this paper is to suggest a standard system of defining the interface which would enable the civil engineer to present the dynamic characteristics of the foundation in a form which the machine designer can use in an improved mathematical model to determine the dynamic behavior of the machine.

#### 81-2530

#### Stresses of Turbo-Generator Shafts and Foundations Caused by Electrical System Faults

Th. Jainski

Technical Univ., Berlin, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 9-16, 10 figs, 11 refs

**Key Words:** Interaction: rotor-foundation, Rotors, Foundations, Electric systems

Turbo-generator shafts and foundations are transiently excited by electrical system faults like terminal short circuits, faulty synchronizing, clearing of network short circuits near to the power plant. Abnormal mechanical stressing in rotor and foundation is caused by pulsating electromagnetic forces. They have to be taken into account by dynamic stress investigations of both structures. An accurate determination of local stress values demands complex mathematical models (FEM) and time-consuming numerical investigations (time-history-method) in order to solve the equations of motion. A large FEM-modeled turbo-shaft and foundation were treated by the exact but time-consuming time-history-method and the response-spectra-method as an economical method of approximation considering the dynamic character of the problem. In addition, the dynamic stress of foundations was evaluated by a quasi static analysis according to the old German Standard DIN 4024.

#### 81-2531

#### Seismic Response of a Flexible Rotor

T. Shimogo and M. Nakano

Keio Univ., Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 321-326, 20 figs, 4 tables, 4 refs

**Key Words:** Rotors, Flexible rotors, Seismic response

The results of seismic response analysis of a flexible rotor supported by two bearings, in which the dynamic properties are represented by linear springs and dampers, are presented. For the simplification of a theoretical treatment the rotor is represented as either a lumped or a uniformly distributed parameter system, and gyroscopic moments are included. The seismic excitations acting on two bearings are assumed to be a stationary Gaussian random process with a dominant frequency such as the El Centro earthquake waveform. In particular, the influences of a flexibility of rotor upon the seismic responses; i.e., the relative displacement of the rotor, the dynamic loading of the bearings, and so on, are studied. Numerical examples of a generator-rotor of 350MW steam power plant indicate the fact that the maximum r.m.s. responses are considerably bigger than those obtained on the assumption of a rigid rotor, due to a decreasing fundamental resonance frequency. Influence of rotor speed on the seismic response is also examined.

#### 81-2532

#### Dynamics of High Speed Rotative Assemblies

D.A. Thurgood

British Aerospace Dynamics Group, Hatfield Div., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 389-393, 7 figs, 1 table, 1 ref

**Key Words:** Compressors, Rotary compressors, Turbomachinery, Balancing techniques, Damping

Presentation is made of the development experience of a series of high speed turbocompressor units for aircraft air-conditioning systems with particular reference to aspects of balancing, shaft response and damping, and excitations from angular contact ball bearings.

#### 81-2533

#### Analysis and Design of Centrifugal Pumps Considering Rotor Dynamics

M. Takagi, O. Matsushita, T. Ino, K. Kikuchi, and K. Komatsu

Vibrations in Rotating Machinery, Proc. 2nd Int'l. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 43-51, 16 figs, 1 table, 11 refs

**Key Words:** Pumps, Centrifugal pumps, Friction excitation

In this paper rotational bending stress analysis of centrifugal pump rotors, imbalance response analysis, stability analysis of self-excited vibration and unsteady response analysis due to rubbing are developed. Systematic tests corresponding to these analyses are carried out using actual multi-stage centrifugal pumps. The calculated values agreed well with the experimental values with regard to the stability-threshold speed, and the steady state rotational bending stresses. Qualitative agreement was obtained with regard to the behavior of transient stress due to rubbing. On the basis of these results, methods of estimating the vibration responses and bending stresses in the high speed large-scale multi-stage centrifugal pumps, and pump design methods considering these factors are established.

## RECIPROCATING MACHINES

**81-2534**

**Energy Conservation and Noise Control in Pneumatic Devices and Systems, Part II - Percussive Tools, Blow-offs and Air Ejectors**

M.D. Oviatt

Richard K. Miller & Associates, Inc., Alpharetta, GA, Plant Engineering, 35 (16), pp 116-118 (Aug 6, 1981) 2 figs

**Key Words:** Hand tools, Noise reduction

Noise reduction techniques of hand held reciprocating tools, such as chipping hammers, needle scalers, sand rammers, rock drills, pavement-breakers, blow-off nozzles, and air ejectors, are presented.

## METAL WORKING AND FORMING

(See No. 2664)

## STRUCTURAL SYSTEMS

### BUILDINGS

(Also see Nos. 2561 and 2691)

**81-2535**

**The Tenth Sir Richard Fairey Memorial Lecture: Sound Transmission in Buildings**

M. Heckl

Institut f. Technische Akustik, Technische Universität Berlin, D-1000 Berlin 10, Germany, J. Sound Vib., 77 (2), pp 165-189 (July 22, 1981) 22 figs, 2 tables, 27 refs

**Key Words:** Buildings, Sound transmission

Sound transmission through walls, ceilings, windows, doors, etc., depends on (1) mass per unit area, (2) bending stiffness, (3) damping, (4) variation in bending stiffness (because of struts or other anisotropies), (5) stiffness and damping of interlayers and sound bridges (in cases of double walls), (6) size and shape of partitions, (7) mounting conditions, (8) influence of flanking walls, (9) unwanted effects such as slits, etc. The first three parameters add to a certain degree also the fourth and fifth can be dealt with theoretically by investigating walls of infinite size. In this way many of the results obtained in buildings can be explained at least qualitatively. The influences of size, shape, mounting conditions and the influence of flanking transmission can be understood best by applying energy balance equations, and in this way the average behavior of reasonably large constructions can be explained.

**81-2536**

**Approximate Method for Lateral Load Analysis of High-Rise Buildings**

F.K.E.C. Mortelmans, G.P.J.M. de Roeck, and D.A. Van Gemert

Struct. Engrg. Dept., Katholieke Universiteit Leuven, Belgium, ASCE J. Struc. Div., 107 (ST8), pp 1589-1610 (Aug 1981) 16 figs, 1 table, 7 refs

**Key Words:** Framed structures, Multistory buildings, Buildings, Wind-induced excitation, Columns

An approximate method for the design of long, high-rise buildings under horizontal wind loading is described. The method is based on the reduction of the framed structure to one built-in column with equivalent bending and torsional stiffnesses. Discrete actions of the horizontal members on the columns are distributed over the story heights. The floors are treated as rigid in the horizontal plane. The calculation is reduced to the solution of a system of four linear equations; the determination of internal actions only requires some very simple operations. The accuracy of the method is demonstrated by comparison to the displacement method.

**81-2537**

**Torsional Coupling and Earthquake Response of Simple Elastic and Inelastic Systems**

C.L. Kan and A.K. Chopra

Dept. of Civil Engrg., Univ. of California, Berkeley, CA, ASCE J. Struc. Div., 107 (ST8), pp 1569-1588 (Aug 1981) 16 figs, 1 table, 8 refs

**Key Words:** Buildings, Earthquake response, Torsional response, Lateral response

The effects are analyzed of torsional coupling on the earthquake response of simple one-story structures in elastic and inelastic ranges of behavior. The structures considered are symmetrical about one principal axis of resistance, resulting in coupling only between lateral displacement along the perpendicular axis and the torsional displacement. Torsional coupling arising only from eccentricity between centers of mass and elastic resistance is considered. Systems with several resisting elements are idealized by a single element model. Response of such a model to a selected earthquake ground motion are presented for a range of the basic structural parameters. The response quantities presented include maximum lateral and torsional deformations of the system as well as maximum deformations of individual columns. The response in the inelastic range of behavior is effected by torsional coupling to generally a lesser degree than elastic response.

**FOUNDATIONS**

(Also see Nos. 2527, 2529, 2530)

**81-2539**

**Plastic Models in Turbomachinery Foundation Studies**

R.L. Bannister and J.K. Aneja

Westinghouse Electric Corp., Lester, PA, ASCE J. Engr. Mech. Div., 107 (EM4), pp 649-667 (Aug 1981) 13 figs, 1 table, 22 refs

**Key Words:** Turbomachinery, Machine foundations, Resonant frequencies, Mode shapes, Experimental test data, Model testing

Over a period of years, the static and dynamic behavior of turbomachinery foundations have been studied with scaled plastic models. Experimental data from several investigators show the type of information that can be obtained for resonant frequencies, mode shapes and response levels in the laboratory. Model test data are compared with measurements made on full-size structures and also calculated from analytical models. Accuracy is dependent on the degree to which similitude requirements are met. Experimental results are also presented to show how structural models have been used to determine the effect of foundation termination, rotor unbalance and bearing support stiffness.

**TOWERS**

**81-2538**

**Measurements of Wind and Deformation on a High Radio Tower. Part 3. Measurement (Wind- und Verformungsmessungen an einem Funkturm. Teil 3. Messungen)**

W. Neuerburg

Maschinenlaboratorium 2 der Fachhochschule für Technik Esslingen, Kanalstr, Esslingen, Germany, Techn. Messen-ATM, 7/8, pp 275-280 (July/Aug 1981) 13 figs, 1 ref  
(In German)

**Key Words:** Towers, Wind induced excitation, Experimental test data

The wind loadings on a high tower structure and the coherent effects of static and dynamic responses were studied by means of versatile measurement equipment. Wind pressures against the tower wall, the deformation and oscillation of the structure and the free-streaming wind were measured with reference to the time.

**UNDERGROUND STRUCTURES**

**81-2540**

**Numerical Simulations of Earthquake Effects on Tunnels for Generic Nuclear Waste Repositories**

K.K. Wahi, B.C. Trent, D.E. Maxwell, R.M. Pyke, and C. Young

Science Applications, Inc., Fort Collins, CO, 132 pp (Dec 1980)

DP-1579

**Key Words:** Underground structures, Tunnels, Nuclear waste depositories, Rocks, Seismic waves, Earthquake response, Numerical analysis

The objectives of this generic study were to use numerical modeling techniques to determine under what conditions seismic waves generated by an earthquake might cause instability to an underground opening, or cause fracturing and joint movement that would lead to an increase in the permeability of the rock mass. Three different rock types (salt, granite, and shale) were considered as host media for the repository located at a depth of 600 meters. Special

material models were developed to account for the nonlinear material behavior of each rock type. The sensitivity analysis included variations in the in situ stress ratio, joint geometry, pore pressures, and the presence or absence of a fault. Three different sets of earthquake motions were used to excite the rock mass.

## HARBORS AND DAMS

**81-2541**

**Earthquake Analysis of Concrete Gravity Dams Including Dam-Water-Foundation Rock Interaction**  
A.K. Chopra and P. Chakrabarti  
Univ. of California, Berkeley, CA, Int'l. J. Earthquake Engrg. Struc. Dynam., **9** (4), pp 363-383 (July-Aug 1981) 9 figs, 1 table, 19 refs

**Key Words:** Dams, Concretes, Earthquake damage, Interaction: structure-fluid

A general procedure for analysis of the response of concrete gravity dams, including the dynamic effects of impounded water and flexible foundation rock, to the transverse (horizontal) and vertical components of earthquake ground motion is presented. The problem is reduced to one in two dimensions, considering the transverse vibration of a monolith of the dam. The system is analyzed under the assumption of linear behavior for the concrete, foundation rock and water. The complete system is considered as composed of three substructures -- the dam, represented as a finite element system, the fluid domain, as a continuum of infinite length in the upstream direction, and the foundation rock region as a viscoelastic half-plane. The structural displacements of the dam are expressed as a linear combination of Ritz vectors, chosen as normal modes of an associated undamped dam-rock system. The effectiveness of this analytical formulation lies in its being able to produce excellent results by considering only a few Ritz vectors. The generalized displacements due to earthquake motion are computed by synthesizing their complex frequency responses using Fast Fourier Transform procedures. The stress responses are calculated from the displacements. An example analysis is presented to illustrate results obtained from this analytical procedure. Computation times for several analyses are presented to illustrate the effectiveness of the procedure.

SRI International, Menlo Park, CA, Rept. No. NSF/RA-800421, 50 pp (Sept 1980)  
PB81-174096

**Key Words:** Dams, Dynamic tests, Earthquake simulation

This study explores the feasibility, scope, and cost of dynamic testing of earth and rock-filled dams using explosives to generate the required earthquake-like ground motions. It was concluded that the response of dams to high-level sustained earth shaking, representative of actual earthquakes, can be investigated with explosive array techniques. The dams should be of small to moderate size and should be constructed in a special field test site with moderately strong native soil (not rock). Earth shaking would be provided by contained-explosion arrays that can produce the high-level sustained motion in repeated tests without replacement. It was also concluded that application of strong motion from explosive arrays is not practical because of the risk of damage to the dam or its surroundings.

**81-2543**

**Hydrodynamic and Foundation Interaction Effects in Earthquake Response of a Concrete Gravity Dam**  
A.K. Chopra and S. Gupta  
Univ. of California, Berkeley, CA, ASCE J. Struc. Div., **107** (ST8), pp 1399-1412 (Aug 1981) 15 figs, 3 tables, 8 refs

**Key Words:** Dams, Concretes, Earthquake response

The displacement and stress responses are presented for Pine Flat Dam to the S69E component of the Taft ground motion only, and to the S69E and vertical components acting simultaneously. For each of these excitations, the response of the dam is analyzed four times corresponding to the following four sets of assumptions: (a) Rigid foundation, hydrodynamic effects excluded; (2) rigid foundation, hydrodynamic effects included; (3) flexible foundation, hydrodynamic effects excluded; and (4) flexible foundation, hydrodynamic effects included. Based on these results, the separate effects of dam-water interaction and dam-foundation rock interaction, and the combined effects of the two sources of interaction, on earthquake response of dams are investigated.

## CONSTRUCTION EQUIPMENT

**81-2542**

**Simulation of Strong Earthquake Motion with Contained-Explosion Line Source Arrays, Report on Task 6: Feasibility of Earth Dam Testing**  
P.N. Agrawal and J.R. Bruce

**81-2544**  
**Evaluation of Vibratory Rollers for Bomb Damage Repair**  
K.J. Knox

Engrg. and Services Lab., Air Force Engrg. and Services Ctr., Tyndall AFB, FL, Rept. No. AFESC/ESL-TR-80-43, 71 pp (Aug 1980)  
AD-A096 534

**Key Words:** Compactors, Vibratory techniques, Vibratory tools, Airports

Four vibratory rollers in the 8.5 to 17-ton range were evaluated for use in bomb damage repair of airfields. The rollers were tested for their compaction ability on grade crushed limestone. After this initial testing the two most promising rollers were tested by repairing simulated bomb craters using 24-inch thick layers of crushed limestone compacted only from the surface. These repairs were tested with F-4 load-craft traffic.

The purpose of this report is to summarize the results of a study concerned with the prediction and measurement of noise exposure levels from construction machinery on a site. The relevance of this subject is illustrated by reference to national and international standards and legislation. This study was consummated through the development and validation of prediction and measurement methodologies by considering the following topics: propagation characteristics of noise from stationary and mobile sources over realistic ground surfaces; directivity patterns of noise from construction equipment; transmission of loss characteristics by a building facade; and noise monitoring from construction sites.

#### **81-2545**

#### **Effect of Barriers on Propagation of Construction Noise**

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-113, 147 pp (Dec 1980)

PB81-166829

**Key Words:** Construction equipment, Noise barriers

The study reported is primarily concerned with investigating the effect of barriers on propagation of construction equipment noise and to examine the suitability of some of the more recent and widely used barrier theories. In addition, this study investigates the attenuation afforded by real sized cuttings and embankments with controlled loudspeaker sound source.

#### **81-2547**

#### **Assessment and Propagation of Noise from Conventional and 'Quiet' Pile Drivers**

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-110, 184 pp (Sept 1980)

PB81-168866

**Key Words:** Pile drivers, Noise generation, Sound propagation

This report summarizes the results of a study aimed at defining some of the important basic characteristics of noise from conventional pile drivers, which are considered to be one of the most significant sources of noise annoyance in the community during civil engineering projects, and a range of pile driving devices which were either adapted or designed specifically to generate noise levels below those normally expected from conventional impact pile drivers. The parameters studied were noise levels, spectra and waveform shapes. This study has shown that recent legislation and other stimuli have resulted in a range of pile driving devices whose use, where circumstances permit, results in 10 to 40 dB(A) lower equivalent sound levels being generated by the extensively treated piling rigs as compared with the conventional untreated piling rigs, these reduced noise levels being equal to or less than that produced by other construction site noise sources. In addition, this study investigates the propagation characteristics of noise from pile drivers and also indicates how the noise from such a source is affected by the interposition of a barrier.

#### **81-2546**

#### **Measurement and Prediction of Construction Plant Noise**

H.S. Gill

Inst. of Sound and Vib. Research, Southampton Univ., UK, Rept. No. ISVR-TR-112, 230 pp (Sept 1980)

PB81-166837

**Key Words:** Construction equipment, Noise prediction, Noise measurement

## **POWER PLANTS**

#### **81-2548**

#### **Noise Prediction for Fossil Fuel Power Plants**

S. Shimode and H. Fujita

Mech. Engrg. Res. Lab., Hitachi, Ltd., Tsuchiura, Ibaraki, Japan, Noise Control Engrg., 17 (1), pp 22-29 (July-Aug 1981) 12 figs, 2 tables, 14 refs

**Key Words:** Fossil power plants, Electric power plants, Industrial facilities, Noise reduction

Noise control for large plants is one of the major pollution problems in Japan. Development of a technology for reliable prediction of the noise field for such plants is described. Characteristics of both sound sources and propagation paths are discussed in detail, mainly in reference to turbine housings of fossil fuel power plants. Comparison of the predicted noise field of a power plant with actual measurement showed good agreement and confirmed the usefulness of the prediction program developed.

Rep. Germany, J. Sound Vib., 77 (2), pp 271-285 (July 22, 1981) 7 figs, 2 tables, 16 refs

**Key Words:** Off-shore structures, Drilling platforms, Parameter identification techniques, Damping coefficients

A full scale dynamic test which was incomplete because of rough seas and bad weather conditions and a computational model of the research platform "Nordsee" were the starting points of the work described in this paper. The transient excitation used in the test produced vibrations in the lower frequency range with certain identifiable eigenfrequencies and damping ratios. The identified eigenfrequencies were used as the basis for mass adjustment of the computational model. The computational model consists of a 176 degrees of freedom system, in which the flexible constraints and the virtual mass of water are neglected. The most uncertain data were the masses of the deck body. Parameter sensibility investigations, and a priori knowledge of the system and the test conditions led to an adjustment of the mass matrix partitioned corresponding to subsystems. The adjustment was carried out in a factorial global way, in respect to the defined subsystems. The result is an optimum model corresponding to the chosen loss function; the residuum used concerns the inverse eigenfrequency.

#### 81-2549

#### **Response of a Thermal Barrier System to Acoustic Excitation in a Gas Turbine Nuclear Reactor**

W.S. Betts, Jr. and R.D. Blevins

General Atomic Co., San Diego, CA, Rept. No. CONF-810309-7, 11 pp (Nov 1980)  
GA-A-16016

**Key Words:** Nuclear reactors, Thermal insulation, Acoustic excitation, Vibration analysis

A gas turbine located with a high-temperature gas-cooled reactor induces high acoustic sound pressure levels into the primary coolant (helium). This acoustic loading induces high cycle fatigue stresses which may control the design of the thermal barrier system. This study examines the dynamic response of a thermal barrier configuration consisting of a fibrous insulation compressed against the reactor vessel by a coverplate which is held in position by a central attachment fixture. The results of dynamic vibration analyses indicate the effect of the plate size and curvature and the attachment size on the response of the thermal barrier.

## **VEHICLE SYSTEMS**

### **GROUND VEHICLES**

(Also see Nos. 2564, 2565, 2653, 2684, 2685, 2686)

#### 81-2551

#### **Analyzing Noise with Finite Elements**

Machine Des., 53 (18), pp 148-153 (Aug 6, 1981)  
1 ref

**Key Words:** Motor vehicle noise, Automobiles, Noise generation, Finite element technique

The use of the finite element technique to study noise propagation in intricate cavities is demonstrated by applying it in the analysis of an automobile compartment boom noise. Such noise is produced by cavity resonance excited by wind, loading engine vibration and road roughness. Results of the analysis show that seat shape has a significant effect on cavity resonance, suggesting that some design change may eliminate the booming phenomena.

## **OFF-SHORE STRUCTURES**

#### 81-2550

#### **Parameter Adjustment of a Model of an Offshore Platform from Estimated Eigenfrequencies Data**

H. Natke and H. Schulze

Curt-Risch-Institut f. Schwingungs- und Messtechnik, Universität, Hannover, D-3000 Hannover 1, Fed.

**81-2552****Reduction of Combustion Noise and Structural Improvement of Its Transmission Path in Diesel Engine Design**

Y. Watanabe

Nissan Diesel Motor Co., Ltd., Ageo-shi, Japan,  
Intl. J. Vehicle Des., 2 (3), pp 276-288 (1981) 15  
figs, 2 tables, 3 refs**Key Words:** Trucks, Diesel engines, Noise reduction, Structural modification effects

In order to provide a quieter diesel engine as an essential component of low-noise trucks, a two-year investigation of combustion noise and engine structural analysis was carried out. Influences of various variables related to combustion noise were observed on a Vee type two-cylinder engine, and the variables which seemed to be effective for noise control were confirmed on a multi-cylinder engine. Structural analysis was advanced by using improved measuring techniques such as applications of laser holography, transfer function and F.F.T. Furthermore, the adoption of accelerated running simulation on an eddy-current dynamometer made noise evaluation possible in an engine operating condition that was close to the actual vehicular situation. The target figure of engine noise reduction, 2 to 4 dB(A), could be almost achieved by cylinder block structural modification and turbocharging or by increasing the compression ratio for N.A. engines. Engine noise control techniques found to be effective and their problems are also discussed.

**81-2553****Analysis of Wheel Rail Force and Flange Force During Steady-State Curving of Rigid Trucks**

H. Weinstock and R. Greif

Transportation Systems Ctr., Cambridge, MA, ASME  
Paper No. 81-RT-5**Key Words:** Trucks, Interaction: rail-wheel

The wheel/rail forces and flange forces resulting from steady-state curve negotiation are developed through analysis of a rigid two-axle truck. The analysis provides closed form relations for estimating wheel/rail forces, flange forces, truck angle of attack and sliding conditions for this type of truck as a function of curve radius. The wheel profiles are modeled by conical wheel treads with vertical wheel flanges and flange friction effects are included. The theory used includes both linear and nonlinear creep.

**81-2554****An Application of Stereoscopic Techniques Using****Mobile High-Speed Cameras in Automotive Crash Simulation**

A. Lozzi and J. Chapman

Dept. of Mech. Engrg., Univ. of Sydney, Australia,  
Intl. J. Vehicle Des., 2 (3), pp 299-307 (1981) 6  
figs, 3 refs**Key Words:** Collision research (automotive), Photographic techniques

Parallel axis stereophotography has been applied to record events of an automotive crash simulation. Two 16 mm, high frame rate, high acceleration cameras were used of the type developed for use on board military aircraft. The cameras travelled with the crashing vehicle, and were mounted on a rigid frame which was in turn attached to the floor pan of the vehicle. The crashes referred to here simulated car-to-pole side impacts. The cameras provided a stereoscopic record of events within the body shell's interior during the impact. Displacements and velocities of the anthropomorphic dummies seated in the body shell and of the intrusion caused by the pole, were determined using a single stereo photogrammetric method. Depth measurements were obtained with relative errors of about 1%, or 15 mm.

**SHIPS**

(See No. 2629)

**AIRCRAFT**

(Also see No. 2622)

**81-2555****Structure-Borne Noise Prediction for a Single-Engine General Aviation Aircraft**

J.F. Unruh

Southwest Res. Inst., San Antonio, TX, J. Aircraft, 18 (8), pp 687-694 (Aug 1981) 13 figs, 1 table, 9  
refs**Key Words:** Aircraft noise, Structure-borne noise, Interior noise, Noise prediction, Finite element technique

The usefulness of a deterministic modeling procedure employing structural-acoustic finite-element formulations is investigated for the prediction of structure-borne interior noise. Analytical predictions are compared to normal mode, forced harmonic response, and engine-running experimental data obtained during ground tests of a single-engine general aviation aircraft. From these comparisons, the modeling procedures are shown to be sufficiently accurate for structure-borne interior noise prediction.

**81-2556**

**An Optimization Method for the Determination of the Important Flutter Modes**

E. Nissim and I. Lottati

Technion - Israel Inst. of Tech., Haifa, Israel, J. Aircraft, 18 (8), pp 663-668 (Aug 1981) 11 figs, 4 tables, 9 refs

**Key Words:** Aircraft, Flutter, Optimization

An optimization method for the determination of the dominant flutter modes is presented in this paper. The method is based on the minimization of the quadratic values of sub-determinants derived from the equations of motion. The effectiveness of the method is illustrated by seven numerical examples.

**Key Words:** Aircraft, Crash research (aircraft), Crashworthiness, Design techniques

This program investigated the relationships between aircraft weight, the level of crashworthiness in the design, and the cost and weight associated with crashworthiness elements of the design. Accident and research data were reviewed and actual aircraft designs were analyzed with respect to their levels of crashworthiness and potential improvements. Processing of the data yielded cost and weight curves for use in preliminary design. The curves provide the relationships between gross weight, mean empty weight, levels of crashworthiness, and selected design elements that contribute to crashworthiness for designs employing metallic or composite materials and having gross weights up to 50,000 pounds. Comparisons were made with the current ACAP analyses and results showed good agreement for the weight values and level of crashworthiness.

**81-2557**

**Forced Backward Whirling of Aircraft Propeller-Engine Systems**

S.H. Crandall and J. Dugundji

Massachusetts Inst. of Tech., Cambridge, MA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 265-270, 5 figs, 4 refs

**Key Words:** Aircraft engines, Propellers, Propeller blades, Whirling

Transverse excitation of a light aircraft engine block by the sequential firing of the cylinders can excite a natural mode of vibration which involves backward whirling of the engine at the excitation frequency and propeller blade vibration at a frequency that is the sum of the excitation frequency and the engine speed. The phenomenon is explained in terms of a simplified model with only two non-trivial degrees of freedom.

**81-2559**

**Development of Advanced Techniques for Rotorcraft State Estimation and Parameter Identification**

W.E. Hall, Jr., J.G. Bohn, and J.H. Vincent

Systems Control, Inc., (VT), Palo Alto, CA, Rept. No. NASA-CR-159297, 265 pp (Nov 1980) N81-19098

**Key Words:** Helicopters, Parameter identification techniques

An integrated methodology for rotorcraft system identification consists of rotorcraft mathematical modeling, three distinct data processing steps, and a technique for designing inputs to improve the identifiability of the data. These elements are as follows: (1) a Kalman filter smoother algorithm which estimates states and sensor errors from error corrupted data. Gust time histories and statistics may also be estimated; (2) a model structure estimation algorithm for isolating a model which adequately explains the data; (3) a maximum likelihood algorithm for estimating the parameters and estimates for the variance of these estimates; and (4) an input design algorithm, based on a maximum likelihood approach, which provides inputs to improve the accuracy of parameter estimates. Each step is discussed with examples to both flight and simulated data cases.

**81-2558**

**Crashworthiness Design Parameter Sensitivity Analysis**

A.E. Tanner

Boeing Vertol Co., Philadelphia, PA, Rept. No. USAAVRADCOM-TR-80-D-31, 281 pp (Feb 1981) AD-A096 550

**MISSILES AND SPACECRAFT**

**81-2560**

**Seismic Hazards Studies for Minuteman Missile Wings**

J.C. Battis

Air Force Geophysics Lab., Hanscom AFB, MA,  
Rept. No. AFGL-TR-80-0293, 73 pp (Sept 9, 1980)  
AD-A096 720

**Key Words:** Missiles, Seismic response

Using standard methods of probabilistic seismic risk analysis, estimates of the seismic hazards for six Minuteman missile wings were evaluated. For each site, estimates of the site intensity, acceleration, velocity and displacement annual risk curves were made based on the historical seismicity within 1000 km of each site. Based on these curves, composite design response spectra for 10-, 100-, and 1000-year return period motions were calculated. Plots of the reported earthquake epicenters near each site were also generated. To conduct these studies, a new method for regional modification of peak acceleration attenuation functions was developed and is presented in the appendix to this report.

## MECHANICAL COMPONENTS

### ABSORBERS AND ISOLATORS

(Also see No. 2568)

#### 81-2561

##### Seismic Effectiveness of Tuned Mass Dampers

A.M. Kaynia, D. Veneziana, and J.M. Biggs  
Massachusetts Inst. of Tech., Cambridge, MA, ASCE  
J. Struc. Div., 107 (ST8), pp 1465-1484 (Aug 1981)  
11 figs, 1 table, 22 refs

**Key Words:** Tuned dampers, Single degree of freedom systems, Earthquake response, Buildings

Time history analysis of one degree of freedom systems with and without a tuned mass damper, subjected to a set of historical earthquakes, shows that the peak response ratio (ratio between the peak responses with and without damper) depends primarily on damping constants and on earthquake duration. The same analysis reveals that response ratio values are widely scattered and that the mean response ratio is underestimated by conventional stationary random vibration calculations. Improvement is obtained by considering response movement and broadening of the response spectral density function caused by the damper. Based on these considerations, a probabilistic model is developed that gives the distribution of peak response of buildings modified by addition of a tuned mass damper in terms of the same distribution for the unmodified structures.

#### 81-2562

##### Avoiding Compromise in Engine Mounting

R. Racca  
Barry Controls, Barry Wright Corp., Diesel Progress  
North American, 47 (8), pp 34-36 (Aug 1981)

**Key Words:** Mountings, Engine mounts

The author stresses the importance of proper mounting of an automobile engine, requiring a good understanding of the effect of dynamic loads on the engine. A dynamic analysis procedure is described.

#### 81-2563

##### Design and Performance of Resonant-Cavity Parallel Baffles for Duct Silencing

P.T. Soderman  
U.S. Army Research and Technology Lab., Ames  
Res. Ctr., Moffett Field, CA, Noise Control Engrg.,  
17 (1), pp 12-21 (July-Aug 1981) 18 figs, 1 table,  
25 refs

**Key Words:** Silencers, Baffles, Ducts, Noise reduction

To control noise emission from large ducts, designers often choose some variation of parallel baffles filled with fibrous material. The acoustic performance of such silencers can be very good, but in severe environments they are susceptible to clogging, erosion and settling. There is an alternative - resonant-cavity parallel baffles. This type of baffle, either empty or with a thin absorbent lining pinned to an internal septum, is virtually immune to the above problems. An analytical and experimental study of resonant-cavity baffle silencers, including comparisons with fiberglass-filled baffles, is described.

#### 81-2564

##### Fundamental Study on Semi-Actively Controlled Pneumatic Servo Suspensions for Rail Cars

K. Jindai, K. Kasai, K. Terada, Y. Kakehi, and F.  
Iwasaki  
Japanese Natl. Railways, Tokyo, Japan, ASME Paper  
No. 81-RT-6

**Key Words:** Railroad cars, Suspension systems (vehicles),  
Semiactive isolation

Semi-actively controlled suspension systems were devised to reduce the vibrations of railroad passenger cars. Two

vertical and one lateral pneumatic servo cylinders were mounted parallel to the air springs on each truck. The acceleration signal of the car body above each cylinder was transferred independently to each controller, and the vertical and lateral controllers were adjusted to approximate the results of the optimum analysis of vertical vibration mode and yawing mode respectively.

### 81-2565

#### An Experimental Comparison Between Semi-Active and Passive Suspensions for Air-Cushion Vehicles

D. Hrovat and D.L. Margolis

Dept. of Mech. Engrg., Wayne State Univ., Detroit, MI, Intl. J. Vehicle Des., 2 (3), pp 308-321 (1981)  
9 figs, 2 tables, 15 refs

**Key Words:** Suspension systems (vehicles), Ground effect machines, Dampers, Active damping, Semiactive isolation, Passive isolation

An experimental heave mode model of a tracked air cushion vehicle incorporating on-off semi-active (SA) damper suspension is described. Preliminary tests are conducted to assess the SA pneumatic damper characteristics. For identical sinusoidal ground inputs, the totally passive and on-off SA damping schemes are compared in terms of sprung mass vibration isolation properties. It is shown that the semi-active suspension offers significant advantages over the corresponding passive suspensions, while at the same time requiring only a small amount of control energy.

## BLADES

### 81-2566

#### Further Studies of Bladed Disc Vibration: Effects of Packeting

D.J. Ewins

Imperial College of Science and Tech., London, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 97-102, 5 figs, 12 refs

**Key Words:** Blades, Turbomachinery, Tuning

Various studies made in recent years of the effects of blade mistuning on the vibration characteristics of turbomachine bladed disc assemblies have provided an understanding and

explanation of many of the complex blade vibration phenomena observed under operating conditions. The concepts and techniques introduced in those studies have now been further developed to explore a new range of conditions; namely, where the 'mistuning' is no longer 'small' and is introduced deliberately. Such conditions prevail in bladed assemblies where the blades are grouped in packets either for convenience of assembly (as in steam turbines) or in order to induce a significant detuning of a certain assembly mode. The characteristics of such assemblies are described and their relationship to the corresponding properties of a symmetrical or tuned system established, since the computational effort required to analyze a packeted bladed disc is very much greater than for its continuously-shrouded counterpart.

### 81-2567

#### Stall Flutter of Linear Cascade in Compressible Flow

S. Kaji

Univ. of Tokyo, Tokyo, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 209-214, 6 figs, 5 refs

**Key Words:** Cascades, Jet engines, Fans, Flutter

Stall and non-stall bending mode flutter in high subsonic and supersonic flows is analyzed by the semi-elliptic disc theory. Transonic two-dimensional cascade test data are used for the estimation of total pressure-loss change due to airfoil oscillation. Occurrence of 'resonance flutter' which is different from usual stall flutter is predicted. This flutter arises near the cascade resonance conditions for highly loaded cascades in high Mach number flows. Flutter boundaries obtained for subsonic flows and supersonic flows show quite different variations against the change in flow incidence. It is also shown that the direction of airfoil oscillation has a significant effect on flutter boundaries.

## BEARINGS

(Also see Nos. 2506, 2527, 2659, and 2670)

### 81-2568

#### Gyroscopes with Ball Bearing Suspension

V.F. Zhuravlev and D.M. Klimov

Inst. for Problems in Mechanics, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 367-368, 1 fig, 3 refs

**Key Words:** Bearings, Ball bearings, Gyroscopes, Vibration analysis

Ball bearing suspension, which is often used in gyroscopic devices, constitutes a complex system of many elastic bodies (balls, rings, retainers). Special coordinates introduced allow calculation of the potential energy of gyroscopic systems taking into account all possible imperfections in ball bearings. The linear equations of motion of rotor in nonideal ball bearings derived define the spectrum and the level of vibration. The nonlinear equations allow discovery of a few fine phenomena (such as impossibility of exact balancing of rotor in nonideal ball bearings, etc.).

#### 81-2569

#### **Experimental Study of an Inter-Shaft Squeeze Film Bearing**

J.B. Courage

Rolls Royce, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 375-380, 10 figs, 8 refs

**Key Words:** Bearings, Rolling contact bearings, Squeeze-film dampers

The application of squeeze films to the static outer races of rolling element bearings is now common practice in gas turbine engines. However many engines also feature inter-shaft bearings where the benefits of squeeze films could be equally significant. This paper describes an experimental program that has been carried out on a model twin shaft rig to evaluate the feasibility of such a device.

#### 81-2570

#### **Rubber Surface Squeeze Film**

Y. Hori, T. Kato, and H. Narumiya

Dept. of Mech. Engrg., The Univ. of Tokyo, Bunkyo-ku, Tokyo, Japan, J. Lubric. Tech., Trans. ASME, 103 (3), pp 399-405 (July 1981) 13 figs, 10 refs

**Key Words:** Bearings, Squeeze film bearings, Elastomers, Low frequencies, High frequency excitation

Numerical solutions for the squeeze film problem, in which one of the surfaces is made of rubber and moves sinusoidally, are presented. Viscoelasticity and incompressibility of the rubber are taken into account in the numerical procedures. The solutions agree well with the experiments. Variation of the squeeze film shape with time is measured by the moiré

topography. This will be one of the best methods for measuring the film thickness when the lubricating surface is made of soft materials like rubber.

#### 81-2571

#### **Some Damping and Stiffness Characteristics of Angular Contact Bearings under Oscillating Radial Load**

T.L.H. Walford and B.J. Stone

Bearing Res. Ctr., Newark, Notts, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 157-162, 4 figs, 2 tables, 4 refs

**Key Words:** Bearings, Rolling contact bearings, Damping coefficients, Stiffness coefficients, Lubrication

Damping and stiffness measurements are presented for a pair of angular contact bearings which show damping increasing and stiffness decreasing as oil viscosity is reduced. A theoretical model is presented which indicates that the stiffness of the interfaces, between the races and the housing and shaft, is a very significant parameter and is the cause of the observed effect.

#### 81-2572

#### **Magnetic Bearings - A Novel Type of Suspension**

G. Schweitzer and H. Ulbrich

Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 151-156, 10 figs, 12 refs

**Key Words:** Bearings, Magnetic bearings, Rotors

It is well known that a rotor can be supported without contact and without wear by suitable electromagnetic forces. The technical implementation of the basic idea, however, is still rather uncommon. By means of examples the state of the art and possible future trends of the theory and the application of magnetic bearings are demonstrated. One example, the full magnetic suspension of a centrifuge in a vacuum tube, is treated comprehensively.

#### 81-2573

#### **An Instrument for the Measurement of Long-Term**

**Variations of Vertical Bearing Alignments in Turbogenerators**

A. Clapis, G.L. Lapini, and T. Rossini

Centro Informazioni Studi Esperienze, Milano, Italy,  
Vibrations in Rotating Machinery, Proc. 2nd Intl.  
Conf., Churchill College, Cambridge, UK, Sept 1-4,  
1980, organized by Instn. Mech. Engrs., pp 119-124,  
10 figs, 3 refs

**Key Words:** Bearings, Turbogenerators, Alignment, Measurement techniques

A special instrument, called ADE, is described, purposely developed to measure the long-term variations of vertical bearing alignments in turbogenerators. The instrument is based on the communicating vessel principle. A proper number of interconnected cups containing mercury are attached to the machine supports. The liquid level variations in the cups, due to their vertical movements, are measured by proximity transducers fixed on the cup tops. The paper presents a summary of results from measurements by the ADE system on two large turbogenerators where the alignment changes have caused vibration problems.

**81-2574**

**Generation of Squeal/Chatter in Water-Lubricated Elastomeric Bearings**

A.I. Krauter

Tech. Dept., Shaker Research Corp., Ballston Lake,  
NY, J. Lubric. Tech., Trans. ASME, 103 (3), pp  
406-413 (July 1981) 7 figs, 3 tables, 5 refs

**Key Words:** Bearings, Elastomeric bearings, Chatter

This paper presents results from an investigation concerned with vibrational characteristics of compliant-layer water-lubricated bearings. An experimental apparatus emulates the dynamic interactions between the propeller shaft and a water-lubricated elastomeric bearing stave. A computer model predicts the squeal tendency of the experimental apparatus. Correlations are obtained by using the apparatus to verify the predicted squeal tendency. Utilizing the computer model, the effects of varying system parameters on squeal/chatter are determined quantitatively. From the results obtained, it is found that the slope of the friction-speed curve and the effective structural damping are the most important parameters. It is concluded that the essential features of squeal/chatter have been identified and that the phenomenon can be modeled analytically.

**81-2575**

**Dynamically Tuned Gyroscopes and Their Spin Axis Bearings**

D.G. Bonfield and D.J. Haines

Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 327-332, 3 figs, 3 tables, 5 refs

**Key Words:** Bearings, Gyroscopes, Tuning

British Aerospace work on rotor restraint and vibration problems which can limit dynamically tuned gyroscope performance is discussed. The work has resulted through careful design, development and control of critical parts in a series of dynamically tuned gyroscopes to meet missile, aircraft and ship guidance requirements. Gyro rotors mounted on a single gimbal and subject to excitation may now be trimmed to a drift rate of less than 0.1°/hour. For other applications a double gimballed, two axis free rotor unit has been developed in which a number of torsion flexing hinged elements are arranged in a manner similar to two interfaced Hooke's joints but where the freely pivoting hinges of the latter are replaced by torsion cross leaf springs and the intermediate frame members of the couplings act as dynamic gimbals. Drift rates of much less than the above are achieved with these units.

**81-2576**

**Effects of Vibrations Generated by Spin Axis Bearings on Gyroscopic Northfinding Equipment**

B.T. Trayner

Stevenage Div., British Aerospace Dynamics Group, Stevenage, Herts SG1 2DA, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 347-352, 4 figs, 1 table, 3 refs

**Key Words:** Bearings, Gyroscopes, Beat frequency

The paper outlines a particular problem associated with the production of a first generation northfinder due to beating between the angular velocity of the two cages in the spin axis system. This beat frequency was troublesome when very low (with a period of up to 200 seconds) and very low values appeared with an occurrence rate which was higher than would be predicted by the bearing geometry. The practical solution to the problem which was adopted is given and the influence that this had on the design of a second generation northfinder is discussed.

**81-2577**

**On the Steady State and Dynamic Performance Characteristics of Floating Ring Bearings**

C.-H. Li and S.M. Rohde  
Mech. Res. Dept., General Motors Res. Labs., Warren,  
MI, J. Lubric. Tech., Trans. ASME, 103 (3), pp 389-  
397 (July 1981) 18 figs, 13 refs

**Key Words:** Bearings, Floating ring journal bearings, Journal bearings, Periodic response

An analysis of the steady state and dynamic characteristics of floating ring journal bearings has been performed. The stability characteristics of the bearing, based on linear theory, are given. The transient problem, in which the equations of motion for the bearing system are integrated in real time was studied. The effect of using finite bearing theory rather than the short bearing assumption was examined. Among the significant findings of this study is the existence of limit cycles in the regions of instability predicted by linear theory. Such results explain the superior stability characteristics of the floating ring bearing in high speed applications. An understanding of this nonlinear behavior serves as the basis for new and rational criteria for the design of floating ring bearings.

#### 81-2578

#### The Effects of Unbalance on Stability and Its Influence on Non-Synchronous Whirling

R.H. Bannister and J. Makdissi  
Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 395-400, 12 figs, 4 refs

**Key Words:** Bearings, Journal bearings, Hydrodynamic excitation, Whirling, Nonsynchronous vibration

When investigating the behavior of hydrodynamic journal bearings, the criteria for instability is usually defined as a single line on the stability map and no attempt is made to explain the possible working limits between the stable and unstable zones. The work presented is intended as an introduction, explaining the transitional stages of instability and suggests how to estimate the severity of instability by pattern recognition. The influence of nonlinearity of the oil film is also demonstrated, by staging the onset of instability and noting the stabilizing influence made to the bearing for varying magnitudes of unbalance force.

#### 81-2579

#### On the Dynamic Behaviour of Gyroscopic Systems that Include Oil Lubricated Journal Bearings

H. McCallion and P.M. Ware

Dept. of Mech. Engrg., Univ. of Canterbury, Christchurch, New Zealand, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 133-138, 6 figs, 7 refs

**Key Words:** Bearings, Journal bearings, Rotors, Shafts, Gyroscopes

Results are reported from a theoretical study into the influences of a number of system parameters on the stability of a family of systems in conical motion. Each member was comprised of a massive rotor, an elastic shaft and a journal bearing. Small oscillations about a steady running position were studied by linearizing the oil film characteristics and it was found that the higher natural frequency could be unstable even when its value was as high as 0.8 times the spin velocity of the shaft. Whirl velocities greater than 0.5 times the spin velocity are not usually associated with oil whip. It is also shown by numerical simulation that some members of this family of systems may be stable at low amplitudes and unstable at high amplitudes and vice versa.

#### 81-2580

#### Identification of Journal Bearing Coefficients Using a Pseudo-Random Binary Sequence

I.U. Dogan, J.S. Burdess, and J.R. Hewit  
Dept. of Mech. Engrg., Univ. of Newcastle upon Tyne, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 277-281, 4 figs, 8 refs

**Key Words:** Bearings, Journal bearings, Parameter identification techniques, Stochastic processes, Spectrum analysis

A stochastic identification technique based upon spectral analysis has been developed to provide a dynamic model of a journal bearing. An outline of the basic theory is given and the results of experimental work carried out on a laboratory journal bearing are described. Direct and cross transfer functions are derived from the bearing response to pseudo binary excitation and the bearing coefficients determined by optimally fitting theoretical transfer functions to the experimental results.

#### 81-2581

#### Experimental and Analytical Research on a Full Scale Turbine Journal Bearing

G. Diana, D. Borgese, and A. Dufour

Mechanics of Machinery Inst., Milan, Italy, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 309-314, 9 figs, 1 table, 7 refs

**Key Words:** Bearings, Journal bearings, Turbines

The purpose of the research is to determine the statistical and dynamical behavior of a large sized lubricated bearing. A testing campaign has been carried out on a full scale bearing of a low pressure turbine in a 320 MW turbo alternator. The results are compared with analytical ones.

#### 81-2582

#### Experiments on the Dynamic Characteristics of Large Scale Journal Bearings

S. Hisa, T. Matsuura, and T. Someya

Turbine Works, Toshiba Corp., Yokohama, Japan, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 223-230, 9 figs, 1 table, 6 refs

**Key Words:** Bearings, Journal bearings, Stiffness coefficients, Damping coefficients

The dynamic characteristics of large scale journal bearings were studied with special reference to the 20-in. diameter load on pads bearing and 32-in. diameter elliptical bearing. Experiments were carried out in a full scale bearing test rig in which static loads up to 80 tons and dynamic loads between  $\pm 3$  and  $\pm 9$  tons with the frequency ranging from 20 Hz to 60 Hz can be imposed upon the test bearing. Stiffness and damping coefficients in both laminar and turbulent regime were obtained, and some features of the dynamic characteristics of the two bearings are discussed. It is also suggested that the outlet oil temperature should be used as the representative temperature for the oil film viscosity. Coefficients are applied for the unbalance response analysis of large steam turbogenerator rotors in service.

Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 231-238, 12 figs, 4 refs

**Key Words:** Bearings, Journal bearings, Stiffness coefficients, Damping coefficients, Parameter identification techniques, Impact tests

This paper describes an identification method to find system parameters of rotating machines, especially the bearing stiffness and damping coefficients. A rigid rotor, running in journal bearings, is excited by a hammer (pulse testing). Input signals (forces) and output signals (displacements of the rotor) are transformed into the frequency domain and the complex frequency response functions are calculated. Analytical frequency response functions, which depend on the bearing coefficients, are fitted to the measured functions. Stiffness and damping coefficients are the results of an iterative fitting process. Results for a cylindrical bearing are presented and compared with coefficients from other authors.

#### 81-2584

#### Analytical Nonlinear Bearing Calculations Using a Variational Approach

L.E. Barrett, P.E. Allaire, and D.F. Li

Dept. of Mech. and Aerospace Engrg., Univ. of VA, Charlottesville, VA, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 247-252, 3 figs, 9 refs

**Key Words:** Bearings, Journal bearings, Variational methods

A solution to the variational equivalent of Reynolds equation for finite length plain cylindrical and segmented journal bearings is presented. An infinite trigonometric series expansion of the pressure field is assumed and the expansion coefficients are found by minimization of the variational principle. The method is intended for use in nonlinear time transient simulations of rotor-bearing systems where finite difference and finite element solutions are computationally too costly to be employed.

#### 81-2583

#### Identification of Stiffness and Damping Coefficients of Journal Bearings by Means of the Impact Method

R. Nordmann and K. Schöllhorn

Technische Hochschule Darmstadt, Fed. Rep. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK,

#### 81-2585

#### Estimation of Seal Bearing Stiffness and Damping Parameters from Experimental Data

S.B. Childs, D.W. Childs, and J. Dresden

Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Church-

ill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 175-180, 4 figs, 1 table, 19 refs

**Key Words:** Test stands, Measurement techniques, Rotors, Seals, Bearings, Stiffness coefficients, Damping characteristics

A test stand has been constructed to measure displacements and forces related to high performance rotors and their bearings and seals. An existing code for solution of boundary value problems in ordinary differential equations is used to estimate the stiffness and damping parameters for the rotor-bearing-seal. Test results indicate that the test stand and method give a more reliable and economical means of estimating these coefficients than other published means.

## COUPLINGS

### 81-2587

#### The Selection of Couplings for Engine Test Beds

C.A. Beard

Ricardo Consulting Engineers, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 115-118, 3 figs, 2 refs

**Key Words:** Couplings, Test facilities, Engines, Combustion engines, Whirling, Torsional response

Problems exist in the selection of couplings for high speed internal combustion engine testbeds. These are reviewed briefly and an approximate, but safe, method for selecting a suitable coupling for particular duties is given. Reference is made to the need to check whirling characteristics as well as the purely torsional aspects. A number of practical installation requirements are referred to briefly.

## GEARS

(Also see Nos. 2656, 2657, 2671, 2676)

### 81-2586

#### Vibration Spectra from Gear Drives

A.W. Lees and P.C. Pandey

Scientific Services Dept., Ratcliffe-on-Soar, Nottingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 103-108, 4 figs, 3 refs

**Key Words:** Gear drives, Vibration response spectra

Manufacturing errors are known to have a major influence on the dynamic performance and integrity of gear drives. For example, in large pulverizing mill drive trains, some of the low-speed gears are so heavily loaded that they suffer significant wear quite early in life. Usually there is enough metal in the teeth to give many years' service but profile errors result in increased dynamic gear tooth forces in the worn gears, as well as in the other gears in the drive train. It is important to know the magnitude of these increased forces so that, if necessary, remedial action can be taken to avoid premature failure. The complete shaft/bearing system is analyzed as a set of segments, each segment terminated at a gear mesh. Equations of constraint are then applied which impose on the system an amplitude-controlled vibration (which may be both flexural and torsional). It is shown how this leads to a response which contains frequencies that are orders of shaft speed, as well as frequencies which are independent of shaft speed. Good agreement is observed between vibration spectra taken from operational plant items and spectra predicted theoretically.

## FASTENERS

### 81-2588

#### Vibration Aspects of Rolling Mill Horizontal Drives with Reference to Recent Coupling Development

C. Patterson, J.L. Wearing, and J.D. Fletcher

Dept. of Mech. Engrg., Univ. of Sheffield, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 315-320, 5 figs, 2 tables, 6 refs

**Key Words:** Joints (junctions), Universal joints, Metal working, Torsional vibration, Translational response, Vibration control

This paper presents a critical survey of the development and increasing industrial use of Hooke (Carden) joints where high torques are involved. Their use in rolling mill horizontal drives in the metal processing industry is discussed as a specific example and the effects on operating and vibratory behavior identified. The use of these couplings reduces translational and torsional vibratory motion in the mill drives resulting in reduced maintenance, wear and power consumption and improved product quality.

**81-2589**

**Lap Splices in Reinforced Concrete under Impact**

T. Rezansoff, J.O. Jirsa, and J.E. Breen

Dept. of Civil Engrg., Univ. of Saskatchewan, Saskatoon, Saskatchewan, Canada, ASCE J. Struc. Div., 107 (ST8), pp 1611-1628 (Aug 1981) 9 figs, 4 tables, 10 refs

**Key Words:** Bonded structures, Joints (junctions), Beams, Concretes, Reinforced concrete, Impact response

The performance of lap splices subjected to impact loading was studied and compared with that of splices under static loading. Nineteen specimens were tested under impact loading, with failure produced in either one impact, in the three to five impacts of incrementally increasing magnitude, or under either unidirectional or reversed cycling of the impact load. Analytical studies were carried out to help evaluate the experimental data. The impact moment capacity of the splices tested was equal to or greater than the static moment capacity.

**LINKAGES**

**81-2590**

**The Application of Finite Element Methods to the Dynamic Analysis of Flexible Spatial and Co-Planar Linkage Systems**

W. Sunada and S. Dubowsky

School of Engrg. and Applied Science, Univ. of California, Los Angeles, CA, J. Mech. Des., Trans. ASME, 103 (3), pp 643-651 (July 1981) 13 figs, 2 tables, 24 refs

**Key Words:** Linkages, Finite element technique, NASTRAN (computer programs), Component mode synthesis

An analytical method is presented for the dynamics of spatial mechanisms containing complex-shaped, flexible links with application to both high-speed industrial machines and robotic manipulators. Existing NASTRAN-type finite element structural analysis programs are combined with 4 x 4 matrix dynamic analysis techniques and Component Mode Synthesis coordinate reduction to yield a procedure capable of analyzing complex, nonlinear spatial mechanisms with irregularly shaped links in great detail, yet producing a system of equations small enough for efficient numerical integration. The method is applied to two examples.

**VALVES**

**81-2591**

**Pressure Relief Valve Noise Attenuation**

T.R. Bordelon and J.F. Etherington

Dresser Industries, Alexandria, LA, ASME Paper No. 81-PVP-38

**Key Words:** Valves, Pressure regulators, Noise reduction

Noise sources related to safety relief valve discharge piping systems are identified. A brief discussion of noise terminology is presented in conjunction with a method of estimating the magnitude of noise sources. Methods to reduce noise levels along with silencer selection and installation guidelines are presented.

**SEALS**

(Also see No. 2585)

**81-2592**

**Labyrinth Seal Effects on Rotor Whirl Instability**

B.T. Murphy and J.M. Vance

Dept. of Mech. Engrg., Texas A&M Univ., College Station, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 369-373, 3 figs, 1 table, 6 refs

**Key Words:** Seals, Rotors, Whirling

The destabilizing effect of labyrinth seals on rotor whirl was first identified by Alford in 1965. Alford's analytical model included the assumption of choked flow at both the inlet and outlet blades of a two blade seal. This paper points to other information which indicates that choked flow can exist only at the exit blade. Under the latter assumption an analysis is performed for a multibleade labyrinth seal. The effects on rotor response and whirl stability are discussed.

**81-2593**

**Flow Induced Spring Constants of Labyrinth Seals**

H. Benckert and J. Wachter

Institut fuer Thermische Stroemungsmaschinen, Univ. of Stuttgart, Stuttgart, Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill

College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 53-63, 13 figs, 14 refs

**Key Words:** Rotors, Seals, Compressors, Fluid-induced excitation

Self-excited rotor vibrations which are a function of output are being increasingly observed in high-performance turbomachinery, in particular high-pressure compressors. A possible source of these rotor instabilities lies in the dynamic behavior of the labyrinth seals. Information on flow-induced spring constants in these types of machines is necessary to achieve a more effective vibration analysis. The work presented deals with the force patterns in eccentric-mode labyrinth seals, the exciting lateral force components perpendicular to the rotor displacement plane, and the restoring force components in this plane. The discussion includes the effects of operational parameters such as the differential pressure ratio, speed and entry flow conditions as well as the geometry of the labyrinth on the spring characteristics of these components. Stability calculations for a high-pressure steam turbine and a radial compressor demonstrate the application of the results.

Lubric. Tech., Trans. ASME, 103 (3), pp 428-435 (July 1981) 4 figs, 21 refs

**Key Words:** Seals, Rings, Vibration analysis

The motion of a flexibly mounted ring in a mechanical face seal is described in its major three degrees of freedom. The equations of motion include fluid film as well as flexible support forces and moments. These equations are linearized using small perturbation analysis. It is shown that for small perturbation the axial motion is uncoupled with the two angular ones and is always stable. A condition for angular stability is derived relating seal operating conditions to its geometry and other design parameters.

#### 81-2594

#### Elastohydrodynamic Lubrication of Offset O-Ring Rotary Seal

M.S. Kaisi

Kaisi Engrg., Inc., Houston, TX, J. Lubric. Tech., Trans. ASME, 103 (3), pp 414-427 (July 1981) 27 figs, 21 refs

**Key Words:** Shafts, Seals, Elastomeric seals, Lubrication, Elastohydrodynamic properties

A fundamental research into the lubrication mechanism and operation of a new type of rotary shaft seal has been conducted. Optical interference technique was successfully used to study the film profiles with optically smooth elastomer seals. Elastohydrodynamic lubrication was found to exist over a wide range of operating conditions. A study of the other performance variables for the Offset-Seal define its useful application range to be between the Packing-Gland and Face-Seal.

#### 81-2596

#### Analysis of High Pressure Oil Seals for Optimum Turbocompressor Dynamic Performance

R.G. Kirk and J.C. Nicholas

Turbo Machinery Group, Ingersoll-Rand Co., Phillipsburg, NJ, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 125-131, 10 figs, 3 refs

**Key Words:** Seals, Turbocompressors, Rotors, Computer-aided techniques, Vibration analysis

The influence of high pressure oil seal rings on the response and stability of turbocompressors is discussed and a method of analysis presented which can be automated for digital computer simulation. The method of analysis is summarized for calculation of the dynamic characteristics including the influence of sealing pressure and thermal equilibrium of the oil film. The results of automated dynamic simulations of turbocompressor systems, including the influence of oil seals, are presented for both steady-state response and dynamic stability. The advantages and disadvantages of the oil seals with regard to vibration performance are discussed for supercritical operation.

## STRUCTURAL COMPONENTS

### BARS AND RODS

#### 81-2595

#### An Analysis of Mechanical Face Seal Vibrations

I. Etsion and Y. Dan

Dept. of Mech. Engrg., Technion, Haifa, Israel, J.

#### 81-2597

#### Apparent Complex Young's Modulus of a Longitudinally Vibrating Viscoelastic Rod

T. Pritz

Central Research and Design Inst. for Silicate Industry, 1034 Budapest, Becsi ut 126/128, Hungary, J. Sound Vib., 77 (1), pp 93-100 (July 8, 1981) 5 figs, 1 table, 19 refs

**Key Words:** Rods, Viscoelastic properties, Wave propagation, Longitudinal vibration

Longitudinal vibration of a viscoelastic rod with a finite lateral dimension is theoretically analyzed on the basis of the approximate Love theory. The frequency range where the Love theory gives good approximation and its accuracy in that range are determined. The theory predicts that the wave propagation in a viscoelastic rod is not governed solely by the complex Young's modulus of the material at higher frequencies, due to the lateral motion, but by its apparent value. It is shown that the apparent dynamic Young's modulus is smaller and the apparent loss factor is larger than the corresponding actual values for the material. The differences between the apparent and actual values depend on the lateral dimension to wavelength ratio and on the complex elastic constants as well.

## BEAMS

(Also see No. 2511)

### 81-2598

#### Dynamic Response of a Beam with a Geometric Non-linearity

S.F. Masri, Y.A. Mariamy, and J.C. Anderson  
Dept. of Civil Engrg., Univ. of Southern California,  
Los Angeles, CA, J. Appl. Mechanics, Trans. ASME,  
48 (2), pp 404-410 (June 1981) 9 figs, 17 refs

**Key Words:** Beams, Geometric effects, Viscous damping, Harmonic excitation, Random excitation

Analytical and experimental studies were made of the dynamic response of a system with a geometric nonlinearity, which is encountered in many practical engineering applications. An exact solution was derived for the steady-state motion of a viscously damped Bernoulli-Euler beam with an unsymmetric geometric nonlinearity, under the action of harmonic excitation. Experimental measurements of a mechanical model under harmonic as well as random excitation verified the analytical findings. The effect of various dimensionless parameters on the system response was determined.

V.H. Neubert and V.P. Rangaiah  
Pennsylvania State Univ., State College, PA, Intl. J.  
Earthquake Engrg. Struc. Dynam., 9 (4), pp 355-361  
(July-Aug 1981) 5 figs, 2 tables, 5 refs

**Key Words:** Beams, Bernoulli-Euler method, Natural frequencies, Transient response, Lumped parameter method

Further investigation of the three-parameter lumped mass model for the prediction of natural frequencies and transient response of Bernoulli-Euler clamped-clamped beams has resulted in a revised model, which is slightly superior to the original model as it is applicable over a wider frequency range.

### 81-2600

#### Static and Dynamic Analyses of Thick Beams of Bimodular Materials

C.W. Bert and A.D. Tran  
School of Aerospace, Mech. and Nuclear Engrg.,  
Univ. of Oklahoma, Norman, OK, Rept. No. OU-  
AMNE-81-7, 68 pp (July 1981) 21 figs, 14 tables,  
58 refs

**Key Words:** Beams, Timoshenko theory, Transient response, Asymmetry, Stiffness

This report deals with the behavior of beams made of bimodular materials, which have one value for the elastic modulus in tension and another in compression. The transfer-matrix approach is used to investigate the small-deflection response to a variety of loadings, both static and transient. The beam is modeled as a Timoshenko beam; i.e., both transverse shear deformation and rotatory inertia are included. Within each field element, provision is made for a neutral-surface position (locus of points having a zero value for the total axial normal strain) that may vary linearly with axial position within the element. The report consists of two distinct parts: Part I covers the static behavior, while Part II deals with transient dynamic behavior.

## CYLINDERS

(Also see Nos. 2536, 2629, 2673)

## FRAMES AND ARCHES

### 81-2599

#### Beam Models for Predicting Dynamic Elastic Response

### 81-2601

#### Post-Elastic Dynamics of Three-Dimensional Frames

A.G. Gillies and R. Shepherd

Beca, Carter, Hollings & Ferner, Consulting Engrs., Wellington, New Zealand, ASCE J. Struc. Div., 107 (ST8), pp 1485-1501 (Aug 1981) 10 figs, 1 table, 4 refs

**Key Words:** Framed structures, Concretes, Reinforced concrete, Seismic design, Earthquake resistant structures

The time-history response of a three-dimensional reinforced concrete frame structure to concurrent earthquake ground motions is analyzed. Yielding is allowed in both beams and columns by a series of yield surface options selected according to the principal structural actions of the component elements. Comparisons between the behavior patterns arising from unidirectional and concurrent earthquake loading indicate that the nonlinear response predicted by a full three-dimensional analysis is significantly different from the response based on a planar frame idealization. Concurrent loading causes asymmetric distribution of yield as a result of the interaction of the orthogonal displacement components, and this gives rise to an eccentricity between the mass and the instantaneous center of stiffness at some levels in the building. Nominally symmetric buildings can develop torsional responses in moderate earthquakes.

## PANELS

(Also see No. 2650)

### 81-2602

#### Sound Transmission through Elastically Supported Sandwich Panels into a Rectangular Enclosure

S. Narayanan and R.L. Shanbhag

Dept. of Appl. Mechanics, Indian Inst. of Tech., Madras, India, J. Sound Vib., 77 (2), pp 251-270 (July 22, 1981) 5 figs, 3 tables, 14 refs

**Key Words:** Panels, Sandwich structures, Viscoelastic core-containing media, Enclosures, Sound transmission

Sound transmission through viscoelastic sandwich panels into rectangular enclosures is investigated in the low frequency range (0 - 1000 Hz). Both harmonic and stationary random external pressure fields are considered. Two opposite edges of the plate are simply supported while the other two edges are elastically supported. A forced damped normal mode analysis is used for response calculations. Numerical results are presented for different parameters of the viscoelastic core.

## PLATES

### 81-2603

#### Elastic Instability of a Heated Annular Plate under Lateral Pressure

J. Tani

Inst. of High Speed Mechanics, Tohoku Univ., Sendai, Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 399-403 (June 1981) 7 figs, 16 refs

**Key Words:** Plates, Annular plates, Thermal excitation

On the basis of the dynamic version of the nonlinear von Karman equations, a theoretical analysis is performed on the elastic instability of a uniformly heated, thin, annular plate which has suffered a finite axisymmetric deformation due to lateral pressure. The linear free vibration problems around the finite axisymmetric deformation of the plate are solved by a finite-difference method. By examining the frequency spectrum with various asymmetric modes, the critical temperature rise under which the axisymmetric deformation becomes unstable due to the bifurcation buckling is determined, which is found to jump up to 7.2 times within a range of very small lateral pressure.

### 81-2604

#### Vibration of Thick Rectangular Plates of Bimodulus Composite Material

C.W. Bert, J.N. Reddy, W.C. Chao, and V.S. Reddy  
School of Aerospace, Mech. and Nuclear Engrg., The Univ. of Oklahoma, Norman, OK, J. Appl. Mechanics, Trans. ASME, 48 (2), pp 371-376 (June 1981) 6 tables, 20 refs

**Key Words:** Plates, Rectangular plates, Finite element technique, Small amplitudes

A finite-element analysis is carried out for small-amplitude free vibration of laminated, anisotropic, rectangular plates having arbitrary boundary conditions, finite thickness shear moduli, rotatory inertia, and bimodulus action (different elastic properties depending upon whether the fiber-direction strain is tensile or compressive). The element has five degrees of freedom, three displacements and two slope functions, per node. An exact closed-form solution is also presented for the special case of freely supported single-layer orthotropic and two-layer, cross-ply plates. This solution provides a benchmark to evaluate the validity of the finite-element analysis. Both solutions are compared with numerical results existing in the literature for special cases (all for ordinary, not bimodulus, materials), and good agreement is obtained.

### 81-2605

#### Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 1: Higher-Order Theory

N. Sugimoto

Dept. of Mech. Engrg., Faculty of Engrg. Science,  
Osaka Univ., Toyonaka, Osaka, Japan, J. Appl.  
Mechanics, Trans. ASME, 48 (2), pp 377-382 (June  
1981) 21 refs

**Key Words:** Plates, Flexural vibration

This paper develops a comprehensive higher-order theory for flexural motions of a thin elastic plate, in which the effect of finite thickness of the plate and that of small but finite deformation are taken into account. Based on the theory of nonlinear elasticity for a homogeneous and isotropic solid, the nonlinear equations for the flexural motions coupled with the extensional motions are systematically derived by the moment asymptotic expansion method. Denoting by  $\epsilon$  the ratio of the thickness of the plate to a characteristic wavelength of flexural motions, an order of characteristic deflection is assumed to be  $\epsilon^2$  and that of a characteristic strain  $\epsilon^3$ . The displacement and stress components are sought consistently up to the next higher-order terms than those in the classical theory.

#### 81-2606

#### Nonlinear Theory for Flexural Motions of Thin Elastic Plate, Part 2: Boundary-Layer Theory Near the Edge

N. Sugimoto

Dept. of Mech. Engrg., Faculty of Engrg. Science,  
Osaka Univ., Toyonaka, Osaka, Japan, J. Appl.  
Mechanics, Trans. ASME, 48 (2), pp 383-390 (June  
1981) 13 refs

**Key Words:** Plates, Flexural vibration, Elastic properties, Boundary layer excitation

This paper deals with, as a continuation of Part 1 of this series, the boundary-layer theory for flexural motions of a thin elastic plate. In the framework of the higher-order theory developed in Part 1, three independent boundary conditions at the edge of the plate are too many to be imposed on the essentially fourth order differential equations. To overcome this difficulty, a boundary layer appearing in a narrow region adjacent to the edge is introduced. Using the matched asymptotic expansion method, uniformly valid solutions for a full plate problem are sought. The boundary-layer problem consists of the torsion problem and the plane problem. Three types of the edge conditions are treated, the built-in edge, the free edge, and the hinged edge. Depending on the type of edge condition, the nature of the boundary layer is characterized. After solving the boundary-layer problem, "reduced" boundary conditions relevant to the higher-order theory are established.

#### SHELLS

(Also see No. 2673)

#### 81-2607

#### Dynamic Stability of Truncated Conical Shells under Pulsating Torsion

J. Tani

Inst. of High Speed Mechanics, Tohoku Univ., Sendai,  
Japan, J. Appl. Mechanics, Trans. ASME, 48 (2), pp  
391-398 (June 1981) 7 figs, 1 table, 13 refs

**Key Words:** Shells, Conical shells, Torsional excitation, Periodic excitation

The dynamic stability of clamped, truncated conical shells under periodic torsion is analyzed by the Galerkin method in conjunction with Hsu's results. The instability regions of practical importance are clarified for relatively low frequency ranges. Numerical results indicate that under the purely periodic torsion only the combination instability region exists but that with an increase in the static torsion the principal instability region becomes most significant. The relative openness of the instability regions is found to depend sensitively on the circumferential phase difference of two vibration modes excited simultaneously at the resonance with the same circumferential wave number.

#### 81-2608

#### Vibrations of Cylindrical Shells with Time-Dependent Boundary Conditions

S.Y. Lu

Univ. of Florida, Gainesville, FL, ASME Paper No.  
81-PVP-21

**Key Words:** Shells, Cylindrical shells, Time-dependent parameters, Boundary condition effects

Dynamic edge effects on the vibrations of elastic shells are studied by separation of variables. The linear nonhomogeneous differential equations are satisfied by separating the displacement functions into two parts: a free vibration solution and a particular solution which satisfies the time-dependent boundary conditions. The theory is applied to the solution of the clamped-clamped cylinder with oscillating edges.

#### 81-2609

#### The Effects of Wall Discontinuities on the Propagation of Flexural Waves in Cylindrical Shells

C.R. Fuller

Inst. Sound Vib. Res., Southampton Univ., UK,  
Rept. No. ISVR-TR-106, 64 pp (Mar 1980)  
PB81-168858

**Key Words:** Shells, Cylindrical shells, Pipes (tubes), Vibration isolation, Discontinuity-containing media, Flexural waves

The transmission of flexural type waves through various discontinuities in the walls of cylindrical shells is investigated. Theoretical curves of transmission loss are obtained for different circumferential wavenumbers and wave types, as functions of frequency. Material stiffness and extensional phase speed, together with the relationship between radial vibration amplitude and total wave power of propagation, are important factors which are found to strongly influence wave transmission through discontinuities. Some practical results useful for predicting the performance of typical pipe isolators (in vacuo) are obtained.

#### 81-2610

#### Wave Propagation in a Thin-Walled Viscoelastic Tube Due to Sudden Release of External Loading

T.B. Moodie, J.B. Haddow, and R.J. Tait

Dept. of Mathematics, Univ. of Alberta, Edmonton, Alberta, Canada, Intl. J. Engrg. Sci., 19 (11), pp 1441-1448 (1981) 2 figs, 4 refs

**Key Words:** Shells, Cylindrical shells, Tubes, Viscoelastic properties

An approximate thin shell theory is used to analyze the dynamic response of an axially constrained incompressible viscoelastic cylindrical tube, due to the sudden release of an axially symmetric uniformly distributed line loading. It is assumed that the tube is sufficiently long that end effects can be neglected. The analysis is based on the linear theory of viscoelasticity and a standard viscoelastic material is considered. Numerical results are obtained by the Fast Fourier Transform algorithm and are presented graphically for a wide range of parameter values.

**Key Words:** Shells, Cylindrical shells, Submerged structures, Transient response, Sound waves, Interaction: structure-fluid

An analytical/computational technique previously developed for determining the geometrically and constitutively nonlinear response of a submerged, infinite cylindrical shell to a transverse, transient acoustic wave is used to study the damage behavior of the shell. Incident waves of rectangular pressure-profile are considered, nonlinear transient response computations are performed, and damage results are described in terms of iso-damage curves based on extensional set strain. Results generated through the use of the doubly asymptotic approximation for treatment of the fluid-structure interaction differ appreciably from their exact counterparts.

#### 81-2612

#### Modal Response of Circular Cylindrical Shells with Structural Damping

A.W. Leissa and K.M. Iyer

Dept. of Engrg. Mechanics, Ohio State Univ., Columbus, OH, J. Sound Vib., 77 (1), pp 1-10 (July 8, 1981) 4 figs, 7 tables, 12 refs

**Key Words:** Shells, Circular shells, Cylindrical shells, Periodic excitation, Damping effects, Hysteretic damping, Modal analysis

Although a vast literature exists dealing with the free vibration of circular cylindrical shells, relatively little can be found for the problem of dynamic response due to sinusoidally varying exciting forces, especially when damping exists. In the present work the response of a shell subjected to a sinusoidal radial pressure is studied, when the pressure has the same distribution as the normal mode shape. Structural (hysteresis) damping is considered. For a unit amplitude of exciting pressure, the lowest frequency modes are found to yield the largest resonant response. Because of a small amount of mode coupling, the peak amplitudes are found to be not quite inversely proportional to the strength of the damping, and there is a slight shift in the locations of the resonant peaks.

#### 81-2611

#### Damage Characteristics of an Infinite Cylindrical Shell Excited by a Transient Acoustic Wave

T.L. Geers and C.L. Yen

Palo Alto Res. Lab., Lockheed Missiles and Space Co., Inc., Palo Alto, CA, Rept. No. LMSC-D686495, 29 pp (Mar 1981)  
AD-A096 686

#### 81-2613

#### The Effect of Viscosity on Free Vibrations of Submerged Fluid-Filled Spherical Shells

T.C. Su

Dept. of Civil Engrg., Texas A&M Univ., College Station, TX, J. Sound Vib., 77 (1), pp 101-125 (July 8, 1981) 13 figs, 16 refs

**Key Words:** Shells, Spherical shells, Submerged structures, Fluid-induced excitation, Fluid-filled containers, Viscosity effects

In order to clarify the effect of fluid viscosity on the vibration of submerged elastic shells, the axisymmetric free oscillations of a fluid-filled spherical shell immersed in a sound field are studied. The dynamic response of the shell is determined by the classical normal mode method, while a boundary layer approximation is employed for the fluid medium. In the absence of viscosity, the shell motion is always damped due to the compressibility of the fluid outside the shell. It is shown that, except for the appearance of natural frequencies with a large damping component, the presence of surrounding fluid outside a fluid-filled shell produces only small changes in the real part of the frequency spectra. The analysis of the influence of viscosity reveals that the viscosity has essentially no effect on the frequencies of shells of moderate thickness. However, the viscous damping is predominant for the non-radiating modes of a fluid-filled submerged shell and the damping is due solely to viscosity for all modes if the outer fluid is assumed incompressible.

## PIPES AND TUBES

### 81-2614

**Comparison of LMFBR Piping Response Obtained Using Response Spectra and Time History Methods**  
G. Hulbert

Westinghouse Advanced Reactors Div., Madison, PA,  
ASME Paper No. 81-PVP-28

**Key Words:** Piping systems, Seismic response, Spectrum analysis

The dynamic response to a seismic event is calculated for a piping system using a response spectrum analysis method and two time history analysis methods. The results from the analytical methods are compared to identify causes for the differences between the sets of analytical results. Comparative methods are also presented which help to gain confidence in the accuracy of the analytical methods in predicting piping system structural response during seismic events.

### 81-2615

**The Use of the Split Ring in Modeling Ductile Axial Crack Extension in Pipes**  
A. Emery, M. Perl, A. Kobayashi, and W. Love

Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 151-154 (May 1981) 6 figs, 16 refs

**Key Words:** Pipes (tubes), Crack propagation

An earlier described ring model for the calculation of axial crack propagation in pipes is investigated numerically. The model assumes that the pipe may be divided into a series of rings. Those rings behind the crack are split and those ahead are whole. By calculating the time history of the opening of the ring behind the crack tip and relating this opening displacement to a fracture criterion, the history of the crack tip extension may be computed.

### 81-2616

**A Sensitivity Study on Numerical Analysis of Dynamic Girth Crack Propagation**

A.S. Kobayashi, A.F. Emery, W.J. Love, and A. Jain  
Dept. of Mech. Engrg., Univ. of Washington, Seattle, WA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 169-174 (May 1981) 9 figs, 1 table, 20 refs

**Key Words:** Pipes (tubes), Crack propagation

Dynamic motion of pre-existing girth crack in an axially stressed, 18-in-diameter 316 stainless steel pipe in the presence of large-scale yielding was analyzed by a finite difference shell code. A critical crack tip opening angle (CTOA) was used as a dynamic fracture criterion and the sensitivities of dynamic crack propagation to differences in CTOA, finite differences mesh sizes, initial crack sizes and initial crack bluntnesses, were analyzed numerically. Hold-off times for the onset of dynamic crack propagation nearly doubled and tripled, while terminal crack velocities decreased about 22 percent and 47 percent when the CTOA was increased from 0.10 to 0.19 and to 0.30, respectively. Doubling of the axial length of the initial crack length and an overdriving condition simulated by a larger CTOA did not change the terminal crack velocity.

### 81-2617

**Fluid Elastic Vibration of Tube Array in Cross Flow**  
H. Tanaka and S. Takahara

Aero-Hydraulics Res. Lab., Nagasaki Technical Inst., Mitsubishi Heavy Industries Ltd., Nagasaki, Japan, J. Sound Vib., 77 (1), pp 19-37 (July 8, 1981) 17 figs, 2 tables, 10 refs

**Key Words:** Heat exchangers, Tube arrays, Fluid-induced excitation

It is well-known that a cylinder bundle vibrates in a cross flow. Studies of the vibration have been made and it has been established that the vibration is a fluid elastic vibration. However, this theory, which is based on quasi-static fluid forces, does not always hold good for all vibration phenomena. In the theory used in this paper unsteady fluid dynamic forces are considered, which are induced by the vibrating cylinders. Since theoretical prediction of unsteady fluid dynamic forces is difficult, model tests were conducted to measure the fluid forces. The equations of motion of the cylinders were deduced and critical velocities were calculated by using the measured unsteady fluid dynamic forces. Critical velocity tests were also conducted with cylinders supported by elastic spars. The calculated critical velocities coincided well with the test results. Effects of fluid density on the critical velocity were studied and it was found that the critical velocity in a low density fluid like air is proportional to the one half power of the mass damping parameter, as predicted by the previous theory. However, the critical velocity in a high density fluid is less influenced by the mass damping parameter. The effects of detuning of the natural frequency on the critical velocity were also considered.

### 81-2619

#### **Continuum Solution of Simulated Pipe Whip Problem**

M. Lashkari and V.I. Weingarten

Dept. of Civil Engrg., Univ. of Southern California, Los Angeles, CA, ASCE J. Struc. Div., 107 (ST8), pp 1443-1463 (Aug 1981) 25 figs, 1 table, 8 refs

**Key Words:** Pipe whip, Nuclear power plants, Piping systems

The pipe whip problem is a highly nonlinear problem which, except for special conditions, is usually solved numerically. When a dynamic load is applied to the base of a pipe (striker) whose end impacts another pipe (target), it is possible for both the striker and the target to experience plastic deformations during impact. A finite element solution considering the nonlinear impact problem with material nonlinearity has been carried out. At the point when the material becomes plastic, high frequency oscillations can set up in the continuum model. Experimental data indicate that these oscillations quickly disappear due to material damping. The effects of plasticity are considered, as are Rayleigh damping and nonlinear damping in the target material.

### 81-2618

#### **Ductile Fracture of Pipes and Cylindrical Containers with a Circumferential Flaw**

F. Erdogan and F. Delale

Dept. of Mech. Engrg. and Mechanics, Lehigh Univ., Bethlehem, PA, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 160-168 (May 1981) 14 figs, 1 table, 20 refs

**Key Words:** Pipes (tubes), Fatigue life, Crack propagation, Shells

The paper deals with the problem of ductile fracture of a pipe or cylindrical container having a relatively long and deep circumferential part-through crack or a through crack and subjected to a uniform axial membrane load in the crack region. After describing the evolution of the ductile fracture process, first the results of the elasticity solution for the circumferentially cracked cylindrical shell based on the Reissner's transverse shear theory are presented. The elastic-plastic part-through crack problem is then considered. In the analysis the plastic deformations are approximated by a perfectly plastic layer similar to the conventional Dugdale model. The load carrying capacity of the cylinder is then estimated in various ways by using the crack opening stretch along the leading edge of the crack as the critical load factor.

### DUCTS

(Also see No. 2563)

### 81-2620

#### **Flow-Acoustic Coupling in Ducts**

P.O.A.L. Davies

Inst. Sound Vib. Res., Univ. of Southampton, Southampton, UK, J. Sound Vib., 77 (2), pp 191-209 (July 22, 1981) 10 figs, 2 tables, 22 refs

**Key Words:** Ducts, Discontinuity-containing media, Sound generation

Experimental data for two mechanisms of sound generation at area discontinuities in flow ducts are described and discussed. The first step in the process is the development of an ordered train of vortices in the shear layer produced by a separating flow. Though not themselves strong radiators of sound, such vortices can excite resonators strongly. The acoustic field of the resonator provides the sound waves which synchronize the vortex motion, producing a self-sustaining oscillation. Alternatively, synchronization of the vortex motion with an incident acoustic field from a source upstream can enhance the sound by transferring energy from the mean flow.

## BUILDING COMPONENTS

81-2621

### Effective Width of Floor Systems for Application in Seismic Analysis

F.S. Cotran and W.J. Hall

Dept. of Civil Engrg., Univ. of Illinois at Urbana-Champaign, Rept. No. STRUCTURAL RESEARCH SER-486, UILU-ENG-80-2021, NSF/RA-800428, 96 pp (Nov 1980)

PB81-168296

**Key Words:** Frames, Floors, Steel, Concretes, Seismic excitation

Effective width coefficients for floor systems have been developed for use in the analysis of frames subjected to lateral seismic loads. The method described covers a wide range of practical values of the slab dimensions and can be applied to both steel and concrete frames and to cases of flat slabs as well as slabs with supporting beams. The investigation is based on a parametric study of typical interior panels of floor systems, with and without supporting beams, using elastic finite element analysis to model the behavior of the floor system when the frame is subjected to lateral loads. The theoretical derivation of the method and the procedure employed for the finite element analysis is covered. Results of the study and a proposed simplified method of analysis for estimating the composite properties are presented. Simple examples illustrate application of the method, emphasizing seismic analysis and the resistance of floor systems under dynamic loads.

81-2622

### A Comparison of Community Response to Aircraft Noise at Toronto International and Oshawa Municipal Airports

S.M. Taylor, F.L. Hall, and S.E. Birnie

Dept. of Geography, McMaster Univ., Hamilton, Ontario, Canada, J. Sound Vib., 77 (2), pp 233-244 (July 22, 1981) 2 figs, 4 tables, 15 refs

**Key Words:** Airports, Traffic noise, Aircraft noise, Human response

Debate continues over the validity of a single dose-response relationship to describe annoyance due to transportation noise. Doubts about the appropriateness of a single relationship have centered primarily on the issue of differential response to the same noise level for different sources; e.g., aircraft, road traffic and trains. However, recent work suggests that response may vary for different types of the same source, namely aircraft, dependent upon the character, and specifically the number, of operations. Recent data collected around Toronto International and Oshawa Municipal airports permit a test of differences in four aggregate response variables. For the same NEF level, the percent at all annoyed at the two airports is not statistically different. The percent highly annoyed and the percent reporting speech interference are both significantly greater at Toronto but the percent reporting sleep interruption is greater at Oshawa. These differences can be explained in terms of the operational characteristics of the two airports.

81-2623

### Industrial Noise Pollution - Part 2: Identifying and Controlling Industrial Noise Sources

R.L. Bannister

Steam Turbine-Generator Div., Westinghouse Electric Corp., Lester, PA, Mech. Engrg., 103 (8), pp 24-29 (Aug 1981) 5 figs, 30 refs

**Key Words:** Noise generation, Industrial facilities

It has been reported that the original proposed OSHA workplace noise standards of 85 dB would have cost industry between \$18 billion and \$31 billion (in 1976 dollars) to meet. The compromise standards that OSHA has now worked out will allow 90 dB but will still cost industry about \$250 million. To comply with these newly established requirements, industry will have to examine everything from the design of its products to its manufacturing processes. The causes of excessive noise will have to be determined and effective and economical solutions will then have to be employed either to reduce the noise to acceptable levels or to shield the worker from its damaging impact.

## ELECTRIC COMPONENTS

### GENERATORS

(See No. 2525)

## DYNAMIC ENVIRONMENT

### ACOUSTIC EXCITATION

(Also see Nos. 2545, 2546, 2547, 2548, 2650)

**81-2624**

**Materials for Noise and Vibration Control**

W.E. Purcell

S/V, Sound and Vibration, 15 (7), pp 4-30 (July 1981)

**Key Words:** Materials, Noise reduction, Vibration control, Acoustic absorption, Noise barriers, Vibration damping, Vibration isolation

A comprehensive mini-handbook for the selection and application of commonly available noise and vibration control materials. Basic information is provided on the characteristics of sound absorptive, sound barrier, vibration damping, and vibration isolation materials.

**81-2625**

**Investigation of a Parametric Acoustic Receiving Array for Mobile Applications**

C.R. Clubertson, R.A. Lamb, and D.F. Rohde

Applied Res. Labs., Univ. of Texas at Austin, Austin, TX, Rept. No. ARL-TR-80-53, 40 pp (Nov 5, 1980) AD-A096 563

**Key Words:** Acoustic arrays, Parameter excitation, Underwater sound

The parametric acoustic receiving array (PARRAY) exploits the nonlinearity of acoustic waves in water to achieve directional reception of low frequency acoustic waves using only two high frequency transducers and associated electronics. In mobile applications the parametric receiver will be required to operate under the influence of sensor motion, and in water that is sometimes turbulent. This report describes these two areas of technical risk which are pertinent to the successful implementation of PARRAYs on submarine platforms. Analysis, fabrication, and testing of a phase-locked loop receiver is described.

## SHOCK EXCITATION

**81-2626**

**A Note on Velocity Inversion of Diffracted Waves**

J.K. Cohen and N. Bleistein

Math. and Computer Science Dept., Univ. of Denver,

Denver, CO 80208, Wave Motion, 3 (3), pp 279-282 (July 1981) 4 figs, 12 refs

**Key Words:** Wave propagation

In a recent article, the authors developed and solved an integral equation for determining small variations in propagation speed. Since the field data is high frequency data on the geophysical scale, it is important to verify that the inversion scheme correctly produces phenomena associated with high frequency data. The inversion results obtained for the case of a data set containing an edge and for the case of a data containing a buried focus are presented.

**81-2627**

**Earthquake Research for the Safer Siting of Critical Facilities**

J.L. Cluff

Natl. Academy of Sciences, Washington, DC, 59 pp (1980)

DOE/CH/93003-4

**Key Words:** Life line systems, Earthquake damage

The task of providing the necessities for living, such as adequate electrical power, water, and fuel, is becoming more complicated with time. Some of the facilities that provide these necessities would present potential hazards to the population if serious damage were to occur to them during earthquakes. Other facilities must remain operable immediately after an earthquake to provide life-support services to people who have been affected. The purpose of this report is to recommend research that will improve the information available to those who must decide where to site these critical facilities, and thereby mitigate the effects of the earthquake hazard.

**81-2628**

**Effect of Earth Media on the Seismic Motion of Embedded Rigid Structures**

J.J. Fedock and H.L. Schreyer

Dept. of Civil Engrg., Univ. of Santa Clara, Santa Clara, CA, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 311-327 (July-Aug 1981) 11 figs, 1 table, 26 refs

**Key Words:** Interaction: soil-structure, Seismic waves, Seismic response

A finite element analysis is performed to determine the influence of the choice of a constitutive model for the earth medium upon the response to seismic waves of an embedded rigid structure. The seismic forcing function is characterized by Rayleigh waves with amplitude parameters adjusted to provide identical free-field motion at a surface reference point for one particular sand represented with elastic, plastic and viscoelastic models. Within the limitations of the analysis, the result is that the steady-state rigid body motions of the embedded structure are essentially identical for these constitutive relations and, consequently, it is appropriate to use an elastic representation for the earth medium.

Mech. Engrg. Dept., Univ. of Glasgow, UK, Int'l. J. Vehicle Des., 2 (3), pp 255-275 (1981) 7 figs

**Key Words:** Random vibration, Structural response, Probability density function

This paper considers the whole problem of the description of random processes, with the two objects of revealing the requirements of description in their most general form and indicating in their proper context the simplifications of Gaussianity and stationarity which give rise to the most commonly used results in random vibration analysis. Single-variate processes are considered first, the additional complications of two-variate processes are then treated, and the general n-variate problem is covered.

### 81-2629

#### **Dynamic Crack Propagation in Precracked Cylindrical Vessels Subjected to Shock Loading**

C.H. Popelar, P.C. Gehien, and M.F. Kanninen

Dept. of Engrg. Mechanics, The Ohio State Univ., Columbus, OH, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 155-159 (May 1981) 3 figs, 1 table, 4 refs

**Key Words:** Cylinders, Crack propagation, Ships, Blast response

Previous work has shown that a speed-independent dynamic fracture toughness property can be used in an elastodynamic analysis to describe crack initiation and unstable propagation under impact loading. In this paper, a further step is taken by extending the analysis from simple laboratory test specimens to treat more realistic crack-structure geometries. A circular cylinder with an initial part-through wall crack subjected to an impulsive loading on its inner surface is considered. The crack is in a radial-axial plane and has its length in the axial direction long enough that a state of plane strain exists at the center of the crack. Crack growth initiation and propagation through the wall is then calculated. It is found that, once initiated, crack propagation will continue until the crack penetrates the wall. Crack arrest within the wall does not appear to be possible under the conditions considered in this paper.

### 81-2631

#### **An Elementary Investigation of Local Vibration**

R.E.D. Bishop and S. Mahalingam

Dept. of Mech. Engrg., Univ. College London, UK, J. Sound Vib., 77 (2), pp 149-163 (July 22, 1981) 8 figs, 3 refs

**Key Words:** Harmonic excitation

It is well known that, if a system is subjected to harmonic forced excitation, the response may be resonant only in some localized part of the system. One may refer to a resonant "subsystem" which may, or may not, be "small." The familiar reed vibrometer exemplifies a small resonant subsystem while a tuned absorber is a resonant subsystem that is not small. The implications of this are explored for the particular case of a subsystem that is linked to the remainder of the vibrating system at a single generalized co-ordinate.

## **MECHANICAL PROPERTIES**

### **VIBRATION EXCITATION**

(Also see No. 2624)

### **DAMPING**

(Also see Nos. 2532 and 2565)

### 81-2630

#### **The Description of Random Vibration**

J.D. Robson

### 81-2632

#### **An Attractive Method for Displaying Material Damping Data**

D.I.G. Jones

Air Force Wright Aeronautical Labs., Wright Patterson AFB, OH, J. Aircraft, 18 (8), pp 644-649 (Aug 1981) 13 figs, 17 refs

**Key Words:** Damping coefficients, Damping materials, Data presentation, Nomographs

This paper describes the development of a new reduced-temperature nomogram which greatly facilitates the display and correlation of complex modulus data for a linear thermorheologically simple viscoelastic damping material in such a way that the effects of frequency and temperature can be simultaneously taken into account. The method is based on the well-known temperature-frequency equivalence principle, which allows one to modify the frequency by a factor depending on temperature alone in such a way that complex modulus data points at a given frequency and temperature can be combined into a single set of curves, representing the loss factor and modulus as a function of a single variable, known as the reduced frequency. The superimposition of temperature isotherms completes the nomogram and thereby greatly expands the usefulness of the reduced-frequency graphs by allowing display on a single graph of complex modulus data at any frequency and temperature. This allows the possibility of generating and transmitting engineering data on viscoelastic material behavior to be used in many areas where such materials are being considered for vibration control.

#### 81-2633

#### Dynamic Pressure Determinations in a Squeeze-Film Damper

R. Holmes and M. Dede

School of Engrg. and Appl. Sciences, Univ. of Sussex, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 71-75, 4 figs, 8 refs

**Key Words:** Dampers, Squeeze film dampers, Rotors

A comparison of predicted and measured pressures in a squeeze-film damper under dynamic loading is presented. The relation between these pressures and vibration orbits resulting from rotor unbalance is elucidated.

#### 81-2634

#### Theoretical and Experimental Investigation into the Effectiveness of Squeeze-Film Damper Bearings without a Centralising Spring

R.A. Cookson and S.S. Kossa

Applied Mechanics Group, Cranfield Inst. of Tech., UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 359-366, 7 figs, 1 table, 10 refs

**Key Words:** Dampers, Squeeze film dampers, Bearings, Turbomachinery

An analytical technique has been developed for determining the effectiveness of squeeze-film damper bearings which do not have a centralizing spring. Squeeze-film damper bearings supporting both rigid and flexible rotors have been analyzed and their performance expressed in terms of non-dimensional system parameters. This analysis has indicated certain clearly defined regions, within the framework of these system parameters, in which the designer should work if he is to produce an effective vibration inhibiting device. An experimental investigation has confirmed that the squeeze-film damper bearing without a centralizing spring can be a very effective method of reducing some forms of vibration in turbomachines.

### FATIGUE

(Also see No. 2519)

#### 81-2635

#### Presentation of Failure Analysis Data by the Fatigue Fracture Mechanics Diagram

R.H. Sailors

American Magotteaux Corp., Pulaski, TN, ASME Paper No. 81-PVP-11

**Key Words:** Crack propagation, Fatigue life, Graphic methods

The integrated crack growth rate equation is presented in graphical form as cyclic stress range versus initial flaw size for various constant cyclic lines. The upper bound of the graph is described by single cycle fracture and lower bound is described by an "engineering defined" threshold value of stress intensity. In many instances the fatigue fracture mechanics diagram simplifies presentation of failure analysis data. It also can illustrate the cause of failure whether it be single or multicycle, and indicate corrective measures needed to avoid repetition of the failure.

#### 81-2636

#### Dynamic Fracture Initiation in Metals and Preliminary Results on the Method of Caustics for Crack Propagation Measurements

L.B. Freund, J. Duffy, and A.J. Rosakis

Brown Univ., Providence, RI, ASME Paper No. 81-PVP-15

**Key Words:** Fatigue life, Crack propagation, Metals

Progress is described in the use of an experimental method for studying fracture initiation under dynamic loading conditions in metals. The instrumentation provides unambiguous records of instantaneous average stress on the unfractured ligament and of instantaneous crack opening displacement.

**81-2637**

**An Analysis of, and Some Observations on, Dynamic Fracture in an Impact Test Specimen**

T. Nishioka, M. Peri, and S.N. Atluri  
Georgia Inst. of Tech., Atlanta, GA, ASME Paper No. 81-PVP-18

**Key Words:** Fatigue life, Crack propagation, Steel

Numerical simulations of crack-propagation histories in four cases of dynamic tear test experiments on 4340 steel are performed. The influence of the loss of contact of the specimen at various times with either the supports or the tup or both is critically examined. In each case, the variation of the dynamic K-factor for the simulated crack-propagation history is directly computed.

**81-2638**

**Evaluation of Dynamic Load Combination Fatigue Damage**

Z.N. Ibrahim and S.A. Gabraiel  
Sargent & Lundy Engineers, Chicago, IL, ASME Paper No. 81-PVP-20

**Key Words:** Fatigue life, Root mean squares

The results of the basic and parametric analyses presented in the preceding sections support the engineering practice of adopting the common cycle elimination technique to evaluate the fatigue damage of the combined, uncorrelated, simultaneous occurrences. This includes employing the square root of sum of squares of the maximum response amplitude and/or range of each of these occurrences, throughout the execution of the cycle elimination process.

**81-2639**

**Fatigue Design in Mining Size Reduction Equipment**

V. Svalbonas  
Koppers Co., Inc., York, PA, ASME Paper No. 81-PVP-9

**Key Words:** Mines (excavations), Equipment, Fatigue life

The mining size reduction equipment industry is reviewed regarding efforts to obtain a consistent fatigue design philosophy. Serious structural failures, which have prompted various company efforts in this area, are reviewed. Basic fatigue data are being gathered with the goal of providing consistent design, fabrication and nondestructive examination programs.

**81-2640**

**Parameters and Micromechanisms of Fatigue Crack Growth in Sheet Magnesium Alloy Samples**

N.M. Grinberg and V.A. Serdyuk  
Physico-Technical Inst. of Low Temperatures, Ukrainian Academy of Sciences, Lenin's Prospect, Kharkov, USSR, Intl. J. Fatigue, 3 (3), pp 143-148 (July 1981) 2 figs, 2 tables, 26 refs

**Key Words:** Fatigue life, Crack propagation

Growth rates of part-through and through fatigue cracks have been measured for two magnesium alloys - MA12 and IMV6 - and the micromechanisms of fatigue fracture were studied at all stages of growth. Conclusions about the peculiarities of the kinetics and micromechanisms of part-through and through crack growth, depending on the applied stress amplitudes and alloy structure, are made from a comparison of the results obtained.

**81-2641**

**Tests to Determine the Fatigue Strength of Steel Castings Containing Shrinkage**

L.P. Pook, A.F. Greenan, M.S. Found, and W.J. Jackson  
Natl. Engrg. Lab., East Kilbride, Glasgow, UK, Intl. J. Fatigue, 3 (3), pp 149-156 (July 1981) 12 figs, 5 tables, 18 refs

**Key Words:** Fatigue tests, Steel

Fatigue tests were carried out on low strength steel castings containing deliberately introduced shrinkage defects. Failure

in most tests originated at defects which could be identified on radiographs, but on the basis of the radiographs, it would not have been possible to predict either the site of the failure or the fatigue strength of the individual specimens. Even gross center-line defects had little effect on the fatigue strength of specimens tested in four point bending, although substantially decreasing the strength of specimen tested in tension. A fracture mechanics analysis was attempted but was not satisfactory due to the difficulty in estimating the stress intensity factors for the irregular flaws concerned and because of excessive yielding in many specimens.

#### 81-2642

##### Growth of Surface Fatigue Cracks in a Steel Plate

O. Vosikovsky and A. Rivard

Physical Metallurgy Res. Labs., Ottawa, Ontario, Canada, *Intl. J. Fatigue*, 3 (3), pp 111-115 (July 1981) 8 figs, 1 table, 11 refs

**Key Words:** Fatigue (materials), Crack propagation, Steel, Pipelines

The growth rates of surface fatigue cracks, both on the surface and within the plate, have been measured on an X65 pipeline steel plate. To calculate stress intensity ranges the finite-element solution by Raju and Newman has been used. The resulting fatigue crack growth rates are in good agreement with those measured on single-edge notched specimens. The variation in shape of a growing surface fatigue crack is analyzed and compared with other published measurements and analytical predictions by Nair.

#### 81-2643

##### Probability of Fatigue Failure as a Statistic

A. Tsurui

Engrg. Dept., Kyoto Univ., Kyoto, Japan, *Intl. J. Fatigue*, 3 (3), pp 125-127 (July 1981) 7 refs

**Key Words:** Fatigue life, Random excitation, Statistical analysis

The probability of failure is treated as a statistic from the viewpoint that the probability can be determined only through experimental data. On the basis of a statistical theory for large samples, an asymptotic distribution function for the probability of fatigue failure under stationary random external loading is given and a simple policy for fatigue-proof design is proposed.

#### 81-2644

##### Stress Intensity Factors for Fatigue Cracking of Round Bars

A.S. Salah el din and J.M. Lovegrove

Civil Engrg. Dept., Southampton Univ., Southampton, UK, *Intl. J. Fatigue*, 3 (3), pp 117-123 (July 1981) 11 figs, 2 tables, 18 refs

**Key Words:** Fatigue life, Bars

The stress intensity factor for a single edge crack of either straight or circular front in a round bar has been determined using both the degenerated quarter-point isoparametric finite element and experimental fatigue crack growth data, and compared with values found by earlier investigators. The results of this study confirm that the stress intensity factors for straight edged surface cracks are lower in round bars than in square bars and a comparison of finite element and experimental results indicates that the effective stress intensity factor at the centre of the fatigue crack front in a round bar is 17% greater than its theoretical value. A correction function is proposed to account for the effect on the stress intensity factor of the circular boundary of a round bar.

## EXPERIMENTATION

### MEASUREMENT AND ANALYSIS

#### 81-2645

##### A New Way to Capture Elusive Signals

C. Somers

Biomation Div., Gould Inc., Santa Clara, CA, *Mach. Des.*, 53 (10), pp 111-115 (May 7, 1981)

**Key Words:** Wave analyzers, Measuring instruments

Recently developed devices for capturing high-speed transient signals, the waveform recorders, are described. They are used in applications requiring high speed monitoring of multiple sensors. Monitoring of stress and strain data from high-rate dynamic tests is a typical example.

#### 81-2646

##### A Matched Impedance, Electrostatic Approach to Hydrophone Design

J.A. Clark

Acousto-Optics Lab., Catholic Univ. of America, Washington, DC, J. Sound Vib., 77 (1), pp 51-59 (July 8, 1981) 4 figs, 15 refs

**Key Words:** Hydrophones, Sound transducers, Design techniques

A new type of acoustically transparent capacitor hydrophone is described and demonstrated. The hydrophone is built with a dielectric material between the capacitor plates which is similar in acoustic impedance to that of water. A theoretical model of this matched impedance type of capacitor hydrophone is developed and compared with a theory of air-filled capacitor hydrophones. Unlike the earlier air-filled types of capacitor hydrophones, the sensitivity is found to be independent of frequency and of parameters determining the capacitance of the hydrophone. Amplitude transmission ratios greater than 96% demonstrate the acoustical transparency of the device.

#### **81-2647**

#### **Combining Holography with Speckling for Vibration Analysis**

J. Politch

Dept. of Physics and Dept. of Aeronautical Engrg., Technion City, Haifa, Israel, Israel J. Tech., 18 (5), pp 275-280 (1980) 9 figs, 13 refs

**Key Words:** Vibration analysis, Holographic techniques, Speckle metrology techniques, Optical method

Time average holographic reconstruction describes a family of fringes, proportional to contours of equal height of vibration, without being able to identify directly the "hills" and the "valleys" of the vibrating object. Time average speckle shearing interferometric reconstruction describes another family of fringes, proportional to the contours of equal slope of vibration. Combining the two families of fringes, it is possible to define at every point of a vibrating surface the amplitude and the relative phase of the mechanical vibration.

Modern tests of the vibrational properties of the unassembled top and back plates of a violin are described.

#### **81-2649**

#### **Qualifying Fixtures for Shaker Control with a Micro-modal Analyzer**

L. Enochson and P.J. Traveaux

Time Series Associates, Palo Alto, CA, TEST, 43 (4), pp 14-19, 22 (Aug/Sept 1981) 15 figs, 4 tables

**Key Words:** Test facilities, Shakers, Vibration analysis

In a laboratory specializing in environmental vibration qualifications, a specially designed test fixture was found to cause unusual vibrations. Modal survey performed on the test fixture is described and solutions are given.

#### **81-2650**

#### **Measurement of Transmission Loss of Panels by the Direct Determination of Transmitted Acoustic Intensity**

M.J. Crocker, P.K. Raju, and B. Forssen

Ray W. Herrick Labs., School of Mech. Engrg., Purdue Univ., West Lafayette, IN, Noise Control Engrg., 17 (1), pp 6-11 (July-Aug 1981) 8 figs, 21 refs

**Key Words:** Panels, Sound transmission loss, Measurement techniques

A new method for the determination of the transmission loss of panels has been developed. This method involves the measurement of the incident and transmitted acoustic intensities. The incident intensity is determined from measurements of the space-averaged sound pressure level in a reverberation room on the source side of the panel. The transmitted intensity is measured directly, using a two-microphone technique. One advantage of this new method is that it uses one reverberation room instead of two as used in the conventional transmission suite method. Another advantage is that it makes possible the identification of the energy transmitted through different parts of composite panels.

### **DYNAMIC TESTS**

(Also see Nos. 2585, 2587)

#### **81-2651**

#### **Digital Experimental Techniques Applied to Low Frequency Shake Phenomena**

J.M. O'Keeffe, W.G. Sutcliffe, I. Scheelke, and U. Proepper  
SDRC-Engineering Services (UK/Scan), Ltd., SAE  
Paper No. 810094

**Key Words:** Steering gear, Vibration control, Low frequencies, Structural modification effects, Automobiles

Digital experimental techniques have been used to investigate the dynamic behavior of vehicles. A test program applied these techniques to provide design insight into low frequency shake phenomena. Operating tests defined the forces responsible for low frequency shake using narrow band spectra and order tracking techniques. Total deformation patterns were measured under operating conditions to determine the controlling elements participating in the vibration perceived at the steering wheel. Modal testing of the vehicle provided a mathematical model of the car over the frequency range 10-50 Hz. This model predicted the effect of modifications to the vehicle before they were implemented. The change in steering column response was monitored to assess the effect of these changes. Analytical predictions were confirmed by testing the modified vehicle.

Branch, Transportation Systems Ctr., Cambridge, MA, ASME Paper No. 81-RT-7

**Key Words:** Railroad cars, Dynamic tests, Test facilities

Perturbed tracks provide a controlled means for evaluating the performance of rail vehicles in various dynamic modes, such as hunting, rock-and-roll, pitch-and-bounce, yaw-and-sway, and dynamic curving. This paper describes a systematic approach for designing such tracks and illustrates the methodology as it has been applied to the preliminary design of the tangent and curved perturbed tracks for the stability assessment facility for equipment.

#### **81-2652**

#### **Digital Numerically Controlled Oscillator**

A. Cellier, D.C. Huey, and L.N. Ma  
NASA, Lyndon B. Johnson Space Ctr., Houston, TX, U.S. PATENT-4 241 308, 8 pp (Dec 23, 1980)

**Key Words:** Oscillators, Computer-aided techniques

The frequency and phase of an output signal from an oscillator circuit are controlled with accuracy by a digital input word. Positive and negative alterations in output frequency are both provided for by translating all values of input words so that they are positive. The oscillator reference frequency is corrected only in one direction, by adding phase to the output frequency of the oscillator. The input control word is translated to a single algebraic sign and the digital 1 is added thereto. The translated input control word is then accumulated.

#### **81-2654**

#### **Harmonic Optimization of a Periodic Flow Wind Tunnel**

J.P. Retelle, Jr., J.M. McMichael, and D.A. Kennedy  
U.S. Air Force Academy, CO, J. Aircraft, 18 (8), pp 618-623 (Aug 1981) 7 figs, 1 table, 10 refs

**Key Words:** Test facilities, Wind tunnels, Periodic excitation

This work describes a wind-tunnel modification designed to superpose on the mean velocity sinusoidal longitudinal velocity fluctuations with minimal harmonic content. The technique is presented in light of a theoretical analysis of the low-frequency performance illustrating how harmonic suppression can be achieved with this particular design. Velocity fluctuations are produced by a system of primary rotating vanes and a bypass containing a secondary set of rotating vanes. Experimental data on tunnel performance are also presented. A significant reduction of the second harmonic content of the free-stream velocity oscillations was achieved by adjustment of the bypass flow.

#### **DIAGNOSTICS**

(Also see No. 2679)

#### **81-2653**

#### **Designing Perturbed Test Tracks for Evaluating Rail Vehicle Dynamic Performance**

R. Brantman, A.B. Boghani, and A.D. Little  
Rail Dynamics Projects, Structures and Mechanics

#### **81-2655**

#### **The Role of Sum and Difference Frequencies in Rotating Machinery Fault Diagnosis**

R.L. Eshleman  
Vibration Inst., Clarendon Hills, IL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 145-149, 5 figs, 4 refs

**Key Words:** Diagnostic techniques, Rotating machinery, Sum and difference frequencies

Increased complexity of rotating machinery and demands for higher speeds and greater power have created complex vibration problems. Instrumentation is now available to perform sophisticated frequency analyses of complex vibration signals. This paper is concerned with correlating machinery faults to sum and difference frequencies. Such phenomena as misalignment, antifriction bearing and gear defects, oil whirl, rubs, trapped fluid, and mass unbalance can often be related to sum and difference frequencies.

given. After a discussion of the types of faults which give rise to such sidebands, a number of practical points in the calculation and interpretation of the cepstrum are discussed. Making use of a number of practical examples, the advantages of the cepstrum are elucidated with respect to diagnostic power and repeatability (lack of sensitivity to secondary effects).

### **81-2656**

#### **Fault Diagnosis of Gears Using Spectrum Analysis**

J.I. Taylor

Vibration Specialists, Inc., Tampa, FL, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 163-168, 9 figs, 3 refs

**Key Words:** Diagnostic techniques, Gears, Spectrum analysis, Sum and difference frequencies

Procedures for identifying gear defects and gear meshing problems are described. A defective tooth or teeth generate and excite specific frequencies and pulses. Analysis of the time signal, spectrum frequencies, shape, amplitude, and sum and difference frequencies will reveal which gears have defective teeth, the number of defective teeth on each gear, the number of gears that have defective teeth, and the location of defective teeth with respect to some reference point. The importance of early identification of gear problems is stressed. An actual case history is presented.

### **81-2658**

#### **A New Analysis Procedure for Noise and Vibration Diagnosis of Rotating Machinery**

G. Hauser

Ingenieurbüro f. Technische Akustik, W. Germany, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 381-387, 13 figs

**Key Words:** Diagnostic techniques, Rotating machinery, Noise source identification, Fourier analysis

The time-synchronous time-window analysis is used for noise and vibration diagnosis especially when very compact constructions with a high degree of pulses in noise behavior are examined. In order to locate noise sources, the vibrations of several channels are analyzed in short takes, so that there is an exact coordination with the mechanical process of the machine. The synchronization procedure is achieved through an angle encoder which controls the analyzing system, so that the parts of the mechanical processes are in effect close to the shaft angle in question with an exactitude of 0.1° angle and therefore independent of speed.

### **81-2657**

#### **Advances in the Application of Cepstrum Analysis to Gearbox Diagnosis**

R.B. Randall

Brüel & Kjaer, Naerum, Denmark, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 169-174, 7 figs, 7 refs

**Key Words:** Diagnostic techniques, Gearboxes, Cepstrum analysis

A review of the experience gained in the application of the cepstrum technique to the identification of families of uniformly spaced sidebands in gearbox vibration spectra is

### **81-2659**

#### **Investigating Bearing Failures**

J.K. Bailey, L.R. Stenander, and R.C. Cooper

TRW Bearings Div., Jamestown, NY, Power Transm. Des., 23(8), pp 29-33 (Aug 1981)

**Key Words:** Bearings, Ball bearings, Failure analysis

By studying photographs, much can be learned about premature ball bearing failure that would otherwise be difficult to communicate. A graphic representation of common conditions is presented to help determine some sources of difficulty.

## BALANCING (Also see No. 2532)

**81-2660**

### Protect Against Large Rotor Unbalance

M. L. Adams

Univ. of Akron, OH, Power, 125 (7), pp 52-54 (July 1981) 6 refs

**Key Words:** Bearings, Rotors, Unbalanced mass response

Two catastrophic failures initiated by large rotor unbalance in turbine/generators with fixed-arc journal bearings in fossil-fired plants are described. The data obtained by a nonlinear vibration analysis suggests that such failures could be prevented by pivoted-pad bearings.

**81-2661**

### A Unified Approach to Flexible Rotor Balancing: Outline and Experimental Verification

M.S. Darlow, A.J. Smalley, and A.G. Parkinson

Mechanical Technology, Inc., Latham, NY, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 437-444, 6 figs, 3 tables, 13 refs

**Key Words:** Balancing techniques, Rotors, Flexible rotors, Unified balancing approach, Influence coefficient method, Modal balancing technique

The logical development of an improved balancing procedure is to incorporate certain features of both the influence coefficient and modal methods to combine the advantages of each while eliminating the corresponding disadvantages. Such a unified approach, Unified Balancing Approach (UBA) has been developed and verified experimentally. In this paper, the influence coefficient and modal methods are reviewed to the extent necessary to provide the basis for the unified approach. The UBA procedure is outlined emphasizing its relationship to the parent techniques, and experimental results are presented which verify the effectiveness of this balancing method and illustrate its advantages in a practical application.

**81-2662**

### Development of High-Speed Balancing Technology - Part 1 - Effects of Laser Metal Removal on Material

## Properties and Part 2 - Balancing of Supercritical Shaft under Torque Load

R. DeMuth and E. Zorzi

Mechanical Technology, Inc., Latham, NY, Rept. No. NASA CR-165314, 93 pp (Jan 1981)

**Key Words:** Balancing techniques, Rotors, Flexible rotors

This report presents the tasks performed in the continuous high-speed balancing technology investigation to determine the effects of laser material removal on material properties and establish a balancing methodology that could control unbalance response with the application of axial torque, evaluate this methodology by experimental testing, and compare predicted and experimental results. Also covered in this report is the development, implementation, and testing of an influence coefficient approach to balancing a long, slender shaft under applied-torque conditions.

**81-2663**

### Automatic Balancing of Rotors

A.A. Gusanov and L.N. Shatalov

GOSNII Mashinovedenia, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 457-461, 3 figs, 2 refs

**Key Words:** Rotors, Balancing techniques, Computer-aided techniques

Methods of automatically balancing rotors are classified. Two methods currently in use are described and some of their limitations outlined. A detailed description is given of a new technique employing a controllable electrohydraulic impact to discharge rapidly solidifying liquids on to the light side of an unbalanced rotor.

**81-2664**

### Automatic Balancing of Grinding Wheels

H. Kaliszer

Mech. Engrg. Dept., Univ. of Birmingham, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 421-426, 8 figs, 11 refs

**Key Words:** Balancing techniques, Wheels, Grinding machinery, Computer-aided techniques

A detailed analysis is given of the existing balancing methods with special emphasis of automatic methods including an adaptive control of the balancing cycle. General economic aspects of selecting the most suitable balancing procedure is also given.

#### 81-2667

##### Balancing of Flexible Rotor with Variable Mass

L.J. Cveticanin

Technic of Sciences, V. Vlahovica, Novi Sad, Yugoslavia, Mech. Mach. Theory, 16 (5), pp 507-516 (1981) 14 figs, 18 refs

**Key Words:** Rotors, Flexible rotors, Balancing techniques

A method is given for balancing a flexible rotor with variable mass by use of a method for balancing a flexible rotor with constant mass. The result is a counterweight whose static mass moment varies with time.

#### 81-2665

##### Balancing of a Double Overhung Compressor with Skewed Wheels and a Bowed Shaft

D.J. Salamone, E.J. Gunter, and L.E. Barrett

Centritech Corp., Houston, TX, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 259-264, 10 figs, 4 tables, 13 refs

**Key Words:** Rotors, Compressors, Balancing techniques

This paper includes the effects of a bowed shaft and skewed impeller wheels on the dynamic response and balancing of a double overhung compressor operating near the third critical speed. It is demonstrated that a two plane balance with a single correction weight at each impeller is insufficient to balance this rotor throughout the entire speed range. However, the system can be successfully balanced by the simultaneous application of couple corrections at each of the two overhung impellers.

#### 81-2666

##### Balancing Flexible Rotors as a Problem of Mathematical Programming

M. Balda

Central Res. Inst., SKODA National Corp., Czechoslovakia, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 253-257, 1 fig, 2 tables, 15 refs

**Key Words:** Rotors, Flexible rotors, Balancing techniques, Minimax technique

It is shown that the problem of balancing flexible rotors is a problem of minimax, which is of a nonlinear nature in the general case. It may be solved either by algorithms of mathematical programming or by special algorithms for nonlinear minimax. There are cases for which the problem remains linear within particular iteration steps and may be solved as an  $L_p$ -approximation over a complex domain.

#### 81-2668

##### Processing Surplus Information in Computer Aided Balancing of Large Flexible Rotors

J. Drechsler

Balancing and Vibration Control Dept., ASEA, Sweden, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instrn. Mech. Engrs., pp 65-69, 1 fig, 1 table, 5 refs

**Key Words:** Balancing techniques, Computer aided techniques, Rotors, Flexible rotors

The theory of flexible rotor balancing has thoroughly investigated the minimum number of balancing planes and the minimum amount of information necessary to successful rotor balancing. Practical experience shows, however, that a consistent consideration of surplus balancing planes and surplus information yields much better results and cuts down the production time considerably. Advanced averaging techniques on surplus trial runs and surplus balancing speeds yield a reliable influence coefficient matrix and can even be used to improve the right hand side of the equation system. The continual check on the pivot element size during the elimination process reveals how many and which planes are most suitable to reduce the vibration level. The surplus planes can be used to cut down the magnitude of the balancing weights, thus indirectly improving the rotor performance at operating speed and overspeed considerably.

#### 81-2669

##### Determination of the Unbalance and the Dynamic Characteristics of a Flexible Rotor under Non-Stationary Conditions

L.N. Shatalov

GOSNII Mashinovedenia, Moscow, USSR, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 453-456, 2 figs, 9 refs

**Key Words:** Rotors, Flexible rotors, Balancing techniques

The determination of the unbalance distribution in a flexible rotor is the most difficult part of the balancing process. Investigations in this field are usually based on considerations of stationary or quasi-stationary vibrations. However, results derived by assuming a rotor to have a constant angular velocity may turn out to be not very acceptable, even for a relatively slow passage of the rotor through its critical speed. Such a divergence between the mathematical model and the actual behavior of a rotor system may give rise to errors in the determination of the unbalance distribution in the rotor. An investigation of the dynamic characteristics of flexible rotors in terms of an amplitude-phase-frequency characteristics analysis for a fast rotor transition through a critical speed is described. The rotor behavior is described by means of differential equations for non-stationary vibrations which are solved in terms of the asymptotic method of Bogoliubov and Mitropolsky.

## MONITORING

### 81-2670

#### Monitoring Rolling Contact Bearings under Adverse Conditions

A.G. Ray

Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 187-194, 8 figs, 8 refs

**Key Words:** Monitoring techniques, Rolling contact bearings, Bearings

A significant proportion of rolling contact bearings must be monitored under conditions that can only be considered as adverse. Low and ultra high speeds, difficulty of access and the presence of other more powerful vibration sources are three of the more commonly met situations. In these the ability of currently used techniques to detect damage fails dramatically. The author considers aspects of the above mentioned problems; first describing in some detail the physical nature of the problem, suggesting some solutions and giving two examples of successful detection: the first at low speed, less than 1000 DN, and the second of a gas turbine main bearing failure. The latter is perhaps the most interesting as it was achieved by vibration analysis of the signal from an accelerometer on the outer casing and so combined three of the worst situations.

### 81-2671

#### The Specification and Development of a Standard for Gearbox Monitoring

R.M. Stewart

Machinery Health Monitoring Group, Inst. Sound Vib. Res., Univ. of Southampton, UK, Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 353-358, 3 figs, 1 table, 5 refs

**Key Words:** Monitoring techniques, Gear boxes

The principal objective of this paper is to "float" the idea of a monitoring standard for gearboxes. It is important to understand what such a term means in condition monitoring at the present time. It is a logical way of approaching the gearbox by appreciating the general nature of its problem, by defining and possibly proscribing the application of the various techniques at our disposal, and by laying out the sequence of steps that might be taken on the path towards implementation of a standard procedure. This paper has been written with machinery managers in mind rather than technicians in vibration analysis.

### 81-2672

#### Fine Tuning Mechanical Design

D. McCormick

Des. Engrg., 52 (8), pp 19-34 (Aug 1981) 6 figs

**Key Words:** Monitoring techniques, Measuring instruments

Machinery health monitoring instrumentation and its operation is described.

## ANALYSIS AND DESIGN

### ANALYTICAL METHODS

(Also see No. 2608)

### 81-2673

#### A Finite Element Formulation for Fluid-Structure Interaction in Three-Dimensional Space

R.F. Kulak

Reactor Analysis and Safety Div., Argonne Natl. Lab., Argonne, IL, J. Pressure Vessel Tech., Trans. ASME, 103 (2), pp 183-190 (May 1981) 13 figs, 2 tables, 10 refs

**Key Words:** Interaction: structure-fluid, Finite element technique, Fluid-filled containers

A development is presented for a three-dimensional hexahedral hydrodynamic finite-element. Using trilinear shape functions and assuming a constant pressure field in each element, simple relations are obtained for internal nodal forces. Because the formulation is based upon a rate approach it is applicable to problems involving large displacements. This element is incorporated into an existing plate-shell finite element code. Diagonal mass matrices are used and the resulting discrete equations of motion are solved using an explicit temporal integrator. Results for several problems are presented which compare numerical predictions to closed form analytical solutions. In addition, the fluid-structure interaction problem of a fluid-filled, cylindrical vessel containing internal cylinders is studied.

## MODELING TECHNIQUES

(Also see Nos. 2523, 2631)

### 81-2674

**Simulation of Earthquake Ground Motions Using Autoregressive Moving Average (ARMA) Models**  
N.W. Polhemus and A.S. Cakmak

Dept. of Civil Engrg., School of Engrg. and Applied Science, Princeton Univ., Princeton, NJ, Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp 343-354 (July-Aug 1981) 7 figs, 6 tables, 11 refs

**Key Words:** Simulation, Earthquake simulation, Seismic excitation

Parsimonious representations of recorded earthquake acceleration time series are obtained by fitting stationary autoregressive moving average models after a variance-stabilizing transformation. Simulated acceleration series are then constructed by generating realizations from the fitted stationary models and applying the reverse transformation. As demonstrated on three components of a typical series, the response spectra for the observed and simulated series show good agreement for periods of less than eight seconds. The model parameters for the three components are very similar, suggesting a consistency which could be useful for identifying site-specific characteristics.

### 81-2675

**Basic Course in Finite-Element Analysis - Advanced Techniques**

N.F. Rieger and J.M. Steele  
Stress Technology Inc., Rochester, NY, Machine Des., 53 (17), pp 97-100 (July 23, 1981)

**Key Words:** Finite element technique

The application of finite element technique for dynamic analysis is described.

## NUMERICAL METHODS

### 81-2676

**A New Branching Technique for the Static and Dynamic Analysis of Geared Systems**

L.D. Mitchell  
Mech. Engrg. Dept., Virginia Polytechnic Inst. and State Univ., Vibrations in Rotating Machinery, Proc. 2nd Intl. Conf., Churchill College, Cambridge, UK, Sept 1-4, 1980, organized by Instn. Mech. Engrs., pp 37-42, 5 figs, 2 tables, 13 refs

**Key Words:** Gears, Branched systems, Transfer matrix method

The dynamic analyses of gear-driven drive systems for their dynamic response have traditionally been done by equivalent dynamic system methods. This method and other nodal-based methods cause excessive computational bookkeeping. This paper proposes the use of multi-rotored transfer matrices. The rotors are coupled by a modified Hibner-type transfer matrix at each gear mesh. This method automatically includes the detailed bookkeeping within the matrix operations. The theory is presented, a mesh transfer matrix developed, and a benchmark example solved by conventional means and by the new coupling method. Numerical results are presented for the case of machining error in the gear teeth.

## STATISTICAL METHODS

### 81-2677

**Principle of Supplementarity of Damping and Isolation in Noise Control**  
G. Maidanik

David W. Taylor Naval Ship Res. and Dev. Ctr., Bethesda, MD, J. Sound Vib., 77 (2), pp 245-250 (July 22, 1981) 2 figs, 8 refs

**Key Words:** Statistical energy analysis, Noise reduction, Damping effects, Isolation

The elements of the statistical energy analysis of a complex dynamic system are briefly reviewed. The explicit form of the analysis is given for a complex consisting of two basic dynamic systems. The analysis is cast in a form that underlies the principle of supplementarity of damping and isolation. Briefly, the principle states that in situations in which the application of either damping or isolation to selected strategic portions of a complex dynamic system does not perform satisfactorily in controlling a noise problem, the supplemental application of damping and isolation may perform effectively.

Z. angew. Math. Mech., 61 (1), pp 7-20 (Jan 1981)  
7 figs, 10 refs

**Key Words:** System identification techniques, Diagnostic techniques

The paper investigates nonlinear stochastic systems with piecewise linear characteristics whose multi-dimensional distribution densities are piecewise gaussian and therefore exactly calculable taking into account the necessary continuity and normalization conditions. Applying this approach to a cracked bending oscillator, a spectral analysis is performed leading to the new phenomenon that the one degree of freedom system possesses two resonances the distance of which is a measure for the damage extension.

## PARAMETER IDENTIFICATION

**81-2678**

**Non-Parametric Identification of a Class of Non-Linear Close-Coupled Dynamic Systems**

F.E. Udwadia and C.-P. Kuo

Univ. of Southern California, Los Angeles, CA,  
Intl. J. Earthquake Engrg. Struc. Dynam., 9 (4), pp  
385-409 (July-Aug 1981) 11 figs, 6 tables, 29 refs

**Key Words:** System identification techniques

A non-parametric identification technique for the identification of arbitrary memoryless non-linearities has been presented for a class of close-coupled dynamic systems which are commonly met within mechanical and structural engineering. The method is essentially a regression technique and expresses the nonlinearities as series expansions in terms of orthogonal functions. Whereas no limitation on the type of test signals is imposed, the method requires the monitoring of the response of each of the masses in the system. The computational efficiency of the method, its easy implementation on analogue and digital machines and its relative insensitivity to measurement noise make it an attractive approach to the non-parametric identification problem.

**81-2679**

**The Integration of Nonlinear Stochastic Systems with Applications to the Damage and Ambiguity Identification**

W. Wedig

## DESIGN TECHNIQUES

**81-2680**

**Design Sensitivity Analysis of Planar Mechanism and Machine Dynamics**

E.J. Haug, R. Wehage, and N.C. Barman

Materials Div., College of Engrg., Univ. of Iowa, Iowa City, IA, J. Mech. Des., Trans. ASME, 103 (3), pp 560-570 (July 1981) 8 figs, 5 tables, 14 refs

**Key Words:** Design techniques, Plane mechanisms, Optimum design, Computer aided techniques

A method of formulating and automatically integrating the equations of motion of quite general constrained dynamic systems is presented. Design sensitivity analysis is carried out using a state space adjoint variable method that has been employed extensively in optimal control and structural design optimization. Both dynamic analysis and design sensitivity analysis formulations are automated and numerical solution of state and adjoint differential equations are carried out using a stiff numerical integration method that treats mixed systems of differential and algebraic equations. A computer code that implements the method is applied to two numerical examples.

## COMPUTER PROGRAMS

**81-2681**

**Desktop Instruments for Modal Analysis**

L. Enochson

Time Series Associates, Palo Alto, CA, Mach. Des.,  
53 (10), pp 81-86 (May 7, 1981)

**Key Words:** Measuring instruments, Modal analysis

Microcomputer-based desk top modal analyzers are described which can be operated by individuals unfamiliar with computer programming. In a typical modal analysis, a stick-figure model is developed to represent the geometry of the structure. The structure is then excited and the vibration data fed from transducers into the analyzer. The analyzer displays frequency-response functions from which the user determines the structural resonances where the largest deflections are produced. The analyzer then displays the animated mode shapes for these selected frequencies. By observing how the structure deforms for each of the various modes, the analyst can evaluate the stability of the structure and modify it if necessary to damp out excessive vibration.

of the evaluation work is to assess the inherent characteristics of the nonlinear static, dynamic and eigenvalue solution branches of the program. Several benchmark problems were run to establish the numerical characteristics of the solution algorithms adopted by ADINA.

#### **81-2682**

#### **Evaluation of ADINA. Part I. Theory and Programming Descriptions**

T.Y. Chang and J. Padovan

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-801, 135 pp (June 8, 1980)  
AD-A096 678

**Key Words:** Computer programs, Finite element technique

An evaluation of 1977 ADINA, a general purpose nonlinear finite element program, was conducted. The evaluation work consists of the review of its theoretical basis, nonlinear static and dynamic solution algorithms, and program architecture. A discussion of the program is made with respect to its nonlinear analysis capability and limitations.

#### **81-2683**

#### **Evaluation of ADINA. Part II. Operating Characteristics**

J. Padovan and T.Y. Chang

College of Engrg., Akron Univ., Akron, OH, Rept. No. AUE-802, 158 pp (June 8, 1980)  
AD-A096 681

**Key Words:** Computer programs, Eigenvalue problems, Finite element technique

An advanced evaluation of the various solution algorithms available in the 1977 ADINA was made. The main objective

#### **81-2684**

#### **Truck and Tractor-Trailer Dynamic Response Simulation, Volume 1. Summary Report**

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-1, FHWA-RD-79-123, 22 pp (Dec 1980)  
PB81-174526

**Key Words:** Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

#### **81-2685**

#### **Truck and Tractor-Trailer Dynamic Response Simulation, Volume 2. Technical Report**

T.D. Gillespie, C.C. MacAdam, G.T. Hu, J. Bernard, and C. Winkler

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-85-2, FHWA-RD-79-124, 130 pp (Dec 1980)  
PB81-174534

**Key Words:** Computer programs, Articulated vehicles, Ride dynamics, Braking effects

A computer program for simulating the braking and directional response of heavy vehicles has been developed for the Federal Highway Administration as a tool for investigation of the effects of increased truck size and weight. Designated as the 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:V1,' the program is capable of simulating

trucks, tractor-semitrailers, doubles and triples combinations. Modeling for the vehicle components has been adapted from earlier simulations produced under sponsorship of the Motor Vehicle Manufacturers Association.

form in FORTRAN. The results of NORM2L are compared with those of other computer programs.

## GENERAL TOPICS

### 81-2686

#### Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:VI. Volume 3. User's Manual

T.D. Gillespie, C.C. MacAdam, and G.T. Hu

Highway Safety Res. Inst., Univ. of Michigan, Ann Arbor, MI, Rept. No. UM-HSRI-79-38-1, FHWA-RD-79-125, 276 pp (Dec 1980)

PB81-174542

**Key Words:** Computer programs, Articulated vehicles, Ride dynamics, Braking effects

This document is a User's Manual for the computer-based mathematical simulation program entitled 'Truck and Tractor-Trailer Dynamic Response Simulation - T3DRS:VI' developed in 1979 by the Highway Safety Research Institute/University of Michigan. This manual provides an introduction to the simulation program with a description of its external characteristics sufficient for a user to submit a run and interpret the output obtained.

### 81-2687

#### NORM2L: An Interactive Computer Program for Acoustic Normal Mode Calculations for the Pekeris Model

D.D. Ellis

Defence Research Establishment Atlantic, Dartmouth, Nova Scotia, Rept. No. DREA-TM-80/K, 74 pp (Dec 1980)

AD-A096 548

**Key Words:** Computer programs, Normal modes, Elastic waves, Wave propagation, Sound propagation, Underwater sound

The interactive computer program, NORM2L, calculates the discrete normal modes and acoustic propagation loss for the Pekeris model of the ocean. The Pekeris model is a simple two-layer model in which the two layers represent the seawater and seabed. For many shallow-water environments, the model is a reasonable approximation to the actual physical situation and can be used to investigate acoustic propagation at low frequencies. For ease of future expansion and modification, the program NORM2L is written in modular

## CONFERENCE PROCEEDINGS

### 81-2688

#### Vibrations in Rotating Machinery

Proc. of Second Intl. Conf. held at Churchill College, Cambridge, UK on Sept 1-4, 1980, organized by the Applied Mechanics Group of the Institution of Mechanical Engineers, 461 pp

**Key Words:** Proceedings, Rotating machinery, Bearings, Shafts, Mechanical drives, Gear drives, Balancing techniques

Papers presented at this conference include the seismic response of flexible rotors, modal dynamic simulation of flexible shafts in hydrodynamic bearings, drive trains in printing machines, vibration spectra from gear drives, balancing of flexible rotors as a problem of mathematical programming, and many others. Abstracts of individual papers are listed in the appropriate sections of this issue of the Digest.

## TUTORIALS AND REVIEWS

### 81-2689

#### A 'Road Map' for Stress Analysis

T.G. Krulick

Fuller Co., Bethlehem, PA, Mach. Des., 53 (18), pp 139-143 (Aug 6, 1981)

**Key Words:** Stress analysis

Procedures for solving various stress problems are presented by means of three charts. Chart A shows how to handle static loads in both brittle and ductile materials. Chart B covers reversing loads on ductile structures. Chart C treats fluctuating loads, uniaxial or combined, in ductile materials.

**81-2690**

**Three Traps to Avoid in Noise Control**

T.H. Rockwell

Acoustical Consultant, Chesterland, OH, Plant  
Engrg., 35 (16), pp 99-100 (Aug 6, 1981) 2 figs

**Key Words:** Noise reduction, Machinery vibration, Machinery noise

The aim of this article is to clarify some of the acoustics fundamentals of machinery noise control. It briefly discusses sound absorption, machinery vibration and noise measuring instrumentation.

**CRITERIA, STANDARDS, AND  
SPECIFICATIONS**

**81-2691**

**Logical Analysis of Tentative Seismic Provisions**

J.R. Harris, S.J. Fenves, and R.N. Wright

Ctr. for Building Tech., U.S. Dept. of Commerce,  
Natl. Bureau of Standards, Gaithersburg, MD, ASCE  
J. Struc. Div., 107 (ST8), pp 1629-1641 (Aug 1981)  
6 figs, 2 tables, 4 refs

**Key Words:** Standards and codes, Buildings, Seismic design,  
Earthquake resistant structures

A study is described of the format and expression of the Tentative Provisions for the Development of Seismic Regulations for Buildings developed by the Applied Technology Council. The methods of analysis employed provide objective measures of clarity, completeness and consistency, as well as an alternative formal representation with which to examine the correctness of the provisions. The formal representation of the seismic provisions and the findings of the analysis will assist those concerned with the future development of the provisions and their implementation within the various national standards and model codes.

# ANNUAL AUTHOR INDEX

Aasen, J.O.	2264	Alderson, M.A.H.G.	243	Askar, A.	819, 1319, 1827, 2433
Abbott, D.R.	2117	Alexander, C.M.	1490	Aslam, M.	1277, 1279
Abdel-Ghaffar, A.M.	11, 1596,	Alfredson, R.J.	168, 2183	Aso, K.	2381
	1831	Ali, R.	984	Assedo, R.	268
Abdelhafez, F.A.	300	Allaire, P.E.	69, 71, 72, 76, 315, 493, 500, 586, 1523, 2584	Astley, R.J.	1959, 1960
Abdel-Rahman, A.Y.A.	1068	Allan, A.B.	1430	Atkinson, C.	662
Abdel-Rohman, M.	2310	Allen, R.R.	1462, 2486	Atkinson, J.T.	172
Aboudi, J.	2031	Allen, R.W.	1232	Atkinson, K.	137
Aboul-Ella, F.	732	Allotey, I.A.	780	Atluri, S.N.	459, 460, 539, 836 1130, 1131, 1132, 2637
Abraham, D.	1187, 1189	Alstead, C.J.	1205	Atmatzidis, D.K.	2311
Abrahamson, A.L.	1033, 1293	Alwar, R.S.	117	Atwal, S.J.	984
Abrahamson, G.R.	637	Amazigo, J.C.	2121	Au, Y.H.J.	231
Achenbach, J.D.	388, 1967, 2473	Amini, A.	2195	Aubrun, J.N.	421
Acosta, A.J.	519, 951	Anagnostopoulos, S.A.	2383	Auckland, D.W.	1724
Adachi, T.	1494	Anand, K.K.	2482	Auconi, F.	1349
Adams, D.R.	2109	Anderson, G.S.	149	Auer, B.M.	959
Adams, M.	221	Anderson, J.C.	1907, 2387, 2598	Auersch, L.	1846
Adams, M.L.	723, 864, 1801, 2660	Anderson, L.R.	2266	Austin, S.C.	734
Adams, M.L., Jr.	3, 1538	Anderson, M.S.	1909	Au-Yang, M.K.	2316
Adams, R.D.	1103, 1660	Ando, Z.	1717	Avezard, L.	2341
Affenzeller, J.	1114	Andreau, C.	37, 928	Awaji, H.	1284
Agar, T.J.A.	922	Andrew, C.	809	Axelrod, M.	2229
Agata, H.	1168	Andry, A.N., Jr.	2208	Axt, W.	1855
Agbabian, M.S.	180	Andrzejewski, M.	2431		<b>B</b>
Agrawal, A.B.	1963	Aneja, J.K.	2539		
Agrawal, P.N.	2542	Angelides, D.C.	739, 885		
Agrone, M.	1393	Anspach, W.F.	1537		
Aguilar, F.	1740	Antonelli, R.G.	1821		
Ahlbeck, D.R.	272, 274	Antonopoulos-Domis, M.	1368	Babcock, C.D.	404, 784
Ahmadi, G.	828	Aomura, S.	2143	Babcock, C.D., Jr.	1940, 2406
Ahmed, H.U.	1601	AppaRao, T.A.P.S.	2331	Bacelon, M.	911
Ahmed, K.M.	892	Arendts, J.G.	216	Bachschmid, N.	2513
Ahrlin, U.	49	Argyris, J.H.	1084, 1583	Baczynski, R.	1605
Ahuja, K.K.	170, 2234	Ariman, T.	368, 796, 1785	Badgley, R.H.	706
Aicher, W.	1084, 1583	Aristizabal-Ochoa, J.D.	384	Bagci, C.	2053, 2427
Aida, T.	2305	Armstrong, G.	1580	Bailey, C.D.	2144
Akamatsu, N.	1710	Armstrong, R.E.	149	Bailey, D.A.	1217
Akay, A.	2456	Arnesen, T.	1912	Bailey, J.K.	2659
Akins, H.	578	Arora, A.	2469	Bailey, J.R.	813
Akkas, N.	1007	Arzoumanidis, S.G.	730	Bailey, P.B.	1766
Akkok, M.	585	Asano, N.	1126	Bainum, P.M.	296
Albrecht, H.	302	Ascari, A.	1236	Bajak, I.L.	1514
Albrecht, P.	1938, 2438	Asfar, K.R.	1063	Bakaysa, B.	1116
Albritton, G.E.	1252	Ashby, G.C., Jr.	1970	Baker, G.K.	1536

Baker, L.	1745	Bathelt, H.	1843	Berglund, K.	49
Baker, P.F.	905	Batko, V.	1306	Bergman, L.A.	2030
Baker, W.E.	646	Battis, J.C.	2560	Berkovits, A.	1219
Bakewell, H.P., Jr.	2465	Baudin, M.	37, 928	Bernard, J.	2684, 2685
Balakrishnan, A.V.	1441	Bauer, H.F.	94, 867, 1278, 1947	Bernard, T.	163
Balasubramanian, T.S.	2		2347	Berndt, W.	185
Balda, M.	2666	Bauer, J.	735	Berry, B.F.	1633
Balendra, T.	783, 1190	Baum, N.P.	1356	Berry, R.A.	717
Ball, J.H.	527	Baumeister, K.J.	624, 1292, 1506	Bert, C.W.	625, 776, 1041, 1681, 1937, 2600, 2604
Ball, R.E.	1951	Bayliss, A.	1966	Berthe, D.	2112
Ball, S.J.	270	Beaman, J.J.	2497, 2498	Bertrand, M.	326
Ballato, A.	1529	Beard, C.A.	2587	Besancon, P.	2413
Ballo, I.	1743	Beards, C.F.	999	Beskos, D.E.	423, 1082, 1901, 2024, 2164
Balsara, J.P.	1252	Bechert, D.W.	141	Betts, W.S., Jr.	2315, 2549
Baluch, M.H.	1927	Beck, R.F.	1856	Beucke, K.E.	2097, 2098
Banda, S.S.	1867	Beck, S.A.	1104	Bezine, G.	989
Bandyopadhyay, P.	174	Becker, J.M.	806	Bezler, P.	1149
Banerjee, M.M.	1933	Becker, R.	385	Bhandari, N.C.	350
Bannister, K.A.	552, 2163	Beckert, H.	317	Bhashyam, G.R.	969, 2382
Bannister, R.H.	2578	Beckman, J.M.	1214	Bhaskara Sarma, K.V.	2510
Bannister, R.L.	2539, 2623	Beddoes, T.S.	1057	Bhat, R.B.	2140
Banon, H.	883	Bednar, J.A.	57	Bhat, W.V.	1613
Bapat, V.A.	1080	Bedrosian, B.	1198	Bhattacharjee, M.C.	1520
Barbas, S.T.	2385	Beex, A.A.L.	1138, 2230	Bhattacharya, S.K.	2453
Barbela, M.	1198	Behar, A.	810, 811, 2324	Bhatti, M.A.	1320, 2176
Barez, F.	638	Behring, M.A.	561, 562	Bhushan, B.	1643
Barger, J.E.	673	Beljaev, A.K.	1122	Bickel, D.C.	2467
Bargis, E.	6, 7	Bell, C.E.	1435	Bickel, J.H.	1539
Barlow, R.E.	799	Bell, G.K.	906	Bies, D.A.	103, 1271
Barman, N.C.	2680	Bell, R.	994	Biggs, J.M.	883, 2561
Barnes, G.R.	569	Bellomo, N.	230, 846	Bilek, Z.	455
Baronet, C.N.	395	Belon, B.	858	Biller, R.H.	1208
Barr, A.D.S.	1065	Beltzer, A.I.	427	Billings, S.A.	1775
Barrett, D.C.	1353	Belytschko, T.	544, 862, 970	Billingsley, R.H.	2074
Barrett, L.E.	71, 499, 1523, 2584 2665	Benckert, H.	606, 2593	Birchak, J.R.	480
Barrows, T.M.	36, 1429	Benda, B.J.	347	Birembaut, Y.	722
Barry, K.E.	2270	Bendat, J.S.	1995	Birlik, G.	1039
Barta, D.A.	1502	Bender, E.K.	627	Birman, V.	1264
Bartholomæ, R.	1469	Bendiksen, O.	2101	Birnie, S.E.	51, 817, 934, 2622
Bartholomæ, R.C.	538, 627	Ben-Dor, G.	1708	Bishop, C.R.	1467
Bartlett, J.A.	1892	Benedetto, G.	2005	Bishop, D.E.	1214, 2342
Barton, C.K.	1616, 2338	Benedikter, G.	1992	Bishop, R.A.	2319
Bartsch, O.	289	Benettin, G.	844, 845	Bishop, R.E.D.	925, 927, 2631
Baruch, M.	97	Benham, R.A.	563	Bitter, C.	1444
Bass, R.L.	1274, 1674 1189	Benjamin, M.	2172	Bitzer, J.H.	484
Batcheler, R.P.	236, 1185, 1188, 765	Bennett, J.G.	2069	Bjorkman, M.	49
Bathe, K.	361	Bennetts, R.D.	877	Black, H.F.	486, 2509
Bathe, K.J.	2274	Bentley, L.R.	1810	Black, R.G.	2178
		Bently, D.E.	490, 697	Blackwell, R.H.	1585
		Benton, M.	2093, 2370		
		Berengier, M.	1048		

Blair, D.P.	1979	Boy, P.	229	Buchele, W.F.	577
Blair, G.M.	583	Boyce, L.	1180	Buchheit, R.D.	2519
Blakely, K.D.	1363	Boyd, C.O.	20	Buckens, F.	225
Blanchard, R.D.	910	Boyd, D.M.	447	Bucker, H.P.	1037
Blanks, H.S.	215	Bradshaw, P.M.	972	Budde, C.L.	556
Blaser, D.A.	382, 383, 2233, 2325	Bradshaw, R.J.	576	Bukchin, B.G.	389
Blaszczyk, J.	2082	Braekhus, J.	2264	Bull, M.K.	2416
Blazier, W.E., Jr.	1976	Bragdon, C.R.	2083	Bullock, J.C.	2116
Bleistein, N.	2626	Brain, C.	288	Burdess, J.S.	234, 435, 2580
Blevins, R.D.	2315, 2549	Brannigan, M.	87	Bürger, H.	1606
Bliss, D.B.	1031	Brantman, R.	746, 2653	Burgess, G.	831
Blondeel, E.	1481	Braun, G.W.	1054	Burkhardt, R.L.	573
Blume, J.A.	1916	Braun, S.	186, 190, 201	Burridge, R.	847
Boaz, I.B.	1838	Bräutigam, H.	2018	Burrin, R.H.	1615
Bock, G.	317	Brazier, S.G.	894	Burrows, C.R.	1540, 2240
Bockosh, G.R.	538	Brearley, M.N.	946	Burt, J.W.	696
Bodhankar, V.	1734	Breen, J.E.	2589	Burton, R.A.	1897
Bodlund, K.	1309	Brennen, C.E.	404, 519, 951	Burton, T.D.	1436
Bogdanoff, J.L.	890	Brepta, R.	1169	Buschmann, H.	1092, 2001
Bogdonoff, S.M.	397	Breskman, D.G.	559	Bushnell, J.C.	2467
Boghani, A.B.	2653	Brey, W.	1818	Busse, L.	5
Bohm, G.J.	31, 1825	Brezina, M.	326	Butler, T.A.	467, 2069
Bohn, J.G.	2559	Brigham, G.	672	Butter, K.	1244
Bohn, L.H.	129	Brillhart, R.D.	1104	Buxbaum, O.	1617
Bohnke, W.	614	Brind, R.J.	1967	Buxbaum, S.R.	1348
Boisch, R.	620	Britt, J.R.	1317, 1521	Bycroft, G.N.	253
Boisson, C.	108	Brockhaus, R.	42		C
Boley, B.A.	423, 1082, 1901	Brockman, R.	1618		
Bollinger, G.	631	Broderson, A.B.	144, 2046		
Bolt, B.A.	2068	Broner, N.	1231		
Bonfield, D.G.	2575	Brooks, J.E.	524		
Book, W.J.	1549	Brooks, P.	475	Cabannes, H.	960, 2379
Booker, B.L.P.	258	Brosio, E.	2005	Cady, K.B.	1833
Booker, J.F.	77	Brotherton, T.	190, 201	Cagliostro, D.J.	541
Booker, M.K.	258	Brown, D.L.	2085	Cakmak, A.S.	819, 1319, 1827
Boonstra, H.	1839	Brown, F.W.	323		2433, 2674
Bordelon, T.R.	2591	Brown, J.D.	1088	Caldwell, L.R.	2087
Bordoni, F.	433	Brown, J.E., Jr.	1427	Caldwell, W.N.	65
Borges, H.G.V.S.	466	Brown, N.W.	540	Calistrat, M.M.	2111
Borgese, D.	2581	Brown, K.W.	68	Callabresi, M.L.	1387, 2094
Borruso, P.	907	Brown, R.D.	486, 2509	Camisetti, C.	749
Boseman, J.J.	737	Brown, S.	1677	Camp, T.H.	571
Boucher, R.E.	2003	Brown, S.J.	1199, 1200	Campbell, R.	889
Bouchon, M.	254	Brown, S.J., Jr.	346, 771	Campbell, R.B.	1428
Boudet, R.	93	Brownjohn, J.M.W.	1103	Campbell, R.D.	260, 891
Bourgine, A.	1628	Bruce, J.R.	637, 2542	Campos, L.M.T.	982
Bourne, C.	660	Bruton, R.A.	1085	Candel, S.M.	1448, 2026
Bousman, W.G.	1652	Bryden, J.E.	1313	Cannelli, G.B.	907
Bouwkamp, J.G.	1921	Brynich, J.	409	Cannon, C.	833
Bowen, W.L.	2107	Bucaro, J.A.	2459	Cantrell, J.H.	432
Bowles, E.B.	1274, 1674	Bucciarelli, L.L.	1639	Capecchi, D.	820

Caplan, C.R.	1470	Chen, C.H.	405	Chu, F.H.	2048, 2089, 2269
Carden, H.D.	1872, 1873	Chen, C.K.	1916	Chu, L.	1319
Carey, R.	1629	Chen, C.S.	1364	Chu, L.L.	.819, 1827
Cargill, A.M.	1860, 1957	Chen, E.P.	1527	Chu, M.L.	1677
Carlsen, C.A.	750	Chen, G.	1076	Chuang, A.	764
Carlson, H.W.	1453	Chen, J.C.	48	Chung, C.G.	2034
Carpenter, G.F.	64	Chen, J.H.	2368	Chung, H.	1661, 1678, 1942
Carter, A.D.S.	661	Chen, K.N.	1238	Chung, J.S.	1953, 1954
Caruso, H.J.	719	Chen, L.	67	Chung, J.Y.	382, 383, 2233
Caruthers, J.E.	727	Chen, N.N.S.	318	Chwang, A.T.	1422
Castelli, V.	204	Chen, P.J.	1766	Cipra, R.J.	1554, 1555
Castro, G.	255	Chen, S.S.	377, 1715, 1911	Citerley, R.	408
Caughey, T.K.	.519, 951	Chen, T.	740	Citerley, R.L.	.390, 1951
Cavanaugh, W.J.	245	Chen, T.W.	.280, 898	Civelek, M.B.	1765
Cawley, P.	1103	Chen, Y.	.278, 770	Claar, P.W., II	577
Cazier, F., Jr.	1621	Chen, Y.N.	.131, 378	Clapis, A.	2753
Celep, Z.	.102, 769	Chen, Y.T.	.827	Clark, B.	.691
Cella, A.	398	Cheng, F.Y.	2064	Clark, J.A.	.171, 2646
Cellier, A.	2652	Cheng, H.S.	2113, 2114	Clark, N.H.	.658
Cempel, C.	1113, 2431	Chesta, L.	.938, 1623	Clarkson, B.L.	.1100
Centola, N.	255	Cheung, Y.K.	.1914	Clayton, S.	.892
Ceranoglu, A.N.	.2402, 2403, 2404	Chhapgar, A.F.	2014	Cleghorn, W.L.	.2491
Cermak, G.W.	910	Chia, W.	.465	Clements, D.L.	.1266
Cervenak, J.G.	910	Chiang, F.P.	.1273	Cline, J.E.	.1229
Cevallos-Candau, P.J.	416	Chiarito, V.	.1423, 2066, 2067	Clough, R.W.	.860
Chabrerie, J.	373	Chien, S.	.1835	Clubertson, C.R.	.2625
Chadha, J.A.	.82	Chiesa, M.L.	.1387, 2094	Cluff, J.L.	.2627
Chaiyung, L.	.240, 257	Chikwendu, S.C.	.2442	Coakley, W.S.	.2046
Chakrabarti, P.	2541	Childs, D.W.	.603, 1582, 2291,	Coale, C.W.	.560
Chamieh, D.	.951		.2585	Coats, D.W.	.217
Chan, A.W.	.405	Childs, S.B.	.603, 2585	Coenen, J.H.	.125
Chan, R.H.	.631	Chimenti, D.E.	.1305	Cohen, D.	.2328
Chan, Y.-L.A.	.440	Chiou, K.L.	.1759	Cohen, J.K.	.2626
Chand, G.	.1734	Chipman, R.R.	.1869	Cohen, N.	.172
Chandra, J.	.2161	Chiroio, V.	.431	Colding-Jørgensen, J.	.518
Chandra, S.	.165, 1524	Chivers, J.W.H.	.1533	Collard, S.	.2519
Chang, C.H.	.2159	Chłodziński, J.	.2187	Colton, D.	.1508, 1562
Chang, J.C.H.	.830	Chmúrný, R.	.306, 1235	Combsure, A.	.736
Chang, P.Y.	.2336	Cho, Y.C.	.136	Comstock, T.R.	.163
Chang, T.Y.	.2682, 2683	Choi, H.S.	.735	Condouris, M.A.	.696
Chang, Y.W.	.264	Chombard, J.	.2341	Connor, J.J.	.739
Chao, C.	.1031	Chon, C.T.	.1127	Connors, H.J.	.130
Chao, W.C.	.776, 2149, 2604	Chonan, S.	.775, 778, 1682	Conry, T.F.	.1891, 2036
Chapkis, R.L.	.933	Chondros, T.G.	.184	Contreras, H.	.458
Chapman, J.	.2554	Chopra, A.K.	.773, 1597, 2537,	Cook, R.O.	.2456
Chapman, R.B.	.1609		.2541, 2543	Cooke, P.W.	.1399
Chargin, M.	.408	Chou, A.	.1749	Cookson, R.A.	.174, 2634
Chattot, J.J.	.939	Chow, G.C.	.1486	Cooley, D.B.	.1438
Chaturvedi, G.K.	.2472	Chow, P.L.	.1759	Cooper, P.	.1625
Chen, C.	.24, 399, 1731	Choy, K.C.	.69, 76	Cooper, R.C.	.2659
Chen, C.C.	.368, 796	Christie, A.M.	.540, 543	Cooper, R.E., Jr.	.1363

Copley, J.C.	2086	D	Dede, M.	2633	
Corley, J.E.	528		Deel, C.C., II	976	
Cornell, C.A.	260		Deel, G.W.	1516	
Cost, T.L.	2188		Deen, R.C.	470	
Costantino, C.J.	2043, 2504	Dagalakis, N.G.	2250	DeFerrari, G.	938, 1623
Costello, W.J.	179	Dahan, C.	2340, 2341	Degenkolb, H.J.	241
Cotran, F.S.	2621	Dahl, G.	1547	Degnan, J.R.	504
Courage, J.B.	2569	Dahlberg, T.	903	deGraaf, E.A.B.	953
Coupland, R.O.	690	Dahlke, H.J.	259	DeHoff, R.	1745
Cowley, A.	1923	Dale, A.K.	745	Delale, F.	2618
Cox, P.A.	1274, 1674	Dale, B.	2039	Delil, A.A.M.	953
Coy, J.J.	2303, 2304	Dally, J.W.	1350	Deloach, R.	1862
Crabill, N.L.	1871	Daly, K.J.	2251	Delpak, R.	1005
Craggs, A.	1029	Dalzell, J.F.	2334	Delph, T.J.	413
Craig, J.	1545	D'Ambra, A.	2042	Dermott, L.R.	1369
Craig, J.E.	156, 157	Damm, W.	529	Dempsey, T.K.	1863
Craig, M.J.	1596	Damms, S.M.	1140	DeMuth, R.	2662
Crighton, D.G.	2142	Dan, Y.	2595	Deng, R.-Y.	1870
Craik, R.J.M.	1958	Daniel, B.R.	1505	Dennison, E.E.	394, 526
Crance, C.	1448, 2026	Daniel, W.J.T.	196, 842	Denus, S.	2187
Crandall, S.H.	407, 502, 1074, 1325, 2557	Daniels, J.H.	236, 237, 238, 1185 1186, 1187, 1188, 1189	dePater, A.D.	945
Crane, R.L.	1305	Danner, M.	689	Deregi, A.	2012
Crawley, E.F.	1000, 2009	Darlow, M.S.	700, 1366, 2474	DeSanto, D.F.	356
Crighton, D.G.	979		2661	de Silva, C.W.	684, 2214
Crocker, M.J.	1542, 2650	Das, A.	1128	Desjardins, R.A.	1635
Croll, J.G.A.	1008, 1683	Das, N.C.	2453	Desjardins, S.P.	1222
Crolla, D.A.	744, 745	Das, S.N.	2453	Desmond, R.M.	1020
Cronkhite, J.D.	46	Das Vikal, R.C.	2204	Desmond, T.P.	2445
Crouse, J.E.	875	Dashcund, D.E.	1868	de Souza, V.C.M.	1008, 1683
Crowson, R.D.	2243	Dassios, G.	139	Destuynder, R.	1460
Cubitt, N.J.	91	Datta, P.	1667	Devaux, H.	108
Cullen, W.H.	265	Datta, S.K.	360, 1022, 1498	Devitt, J.	439, 2464
Culver, C.C.	2327	Davall, P.W.	1333	DeVor, R.E.	1464
Culver, L.E.	1343	David, J.W.	1819	Devrieze, L.	1481
Cummings, A.	1036, 1956	Davidson, J.W.	153	De Wachter, L.	322
Cummins, R.J.	1465	Davies, D.E.	1442	Dharmarajan, S.	612
Cunningham, R.	831	Davies, J.C.	106, 1919, 2426	Diana, G.	2513, 2581
Currie, I.G.	1836		2011	Diaz-Tous, I.A.	1416
Currie, R.B.	1	Davies, M.	2054	Dickens, J.M.	1426
Curry, L.W.	1990	Davies, P.O.A.L.	2620	Dickinson, S.M.	986, 2154, 2155
Curti, G.	339	Davies, W.G.R.	2520	Dicus, R.L.	2432
Curtis, A.J.	685	Davis, D.D.	233	Diekhans, G.	1240, 1650, 1815
Curtis, D.	362	Davis, S.	1605, 2326		2525
Curtiss, H.C., Jr.	747	Davis, S.J.	1154, 1228	Dietrich, R.A.	547
Cutchins, M.A.	1246	Dawe, D.J.	109, 983, 1257	Dilger, T.	163
Cvetičanin, L.J.	2667	Dawson, B.	2054	Dillon, D.B.	607
Czarnecki, S.	2428	Dean, P.D.	170	DiMaggio, F.L.	2160
Czechowicz, M.	2428	Dear, T.A.	1510	Dimarogonas, A.D.	184, 1171
		Dease, C.W.	233	Dimmer, J.P.	1538
		DebChaudhury, A.	829, 1990	Dinyavari, M.	1835
				Dittmar, J.H.	143

Dittrich, G. .... 876  
 Dixon, N.R. .... 627, 1202  
 Doak, P.E. .... 1047  
 Dobbs, M. .... 1835  
 Dobbs, M.W. .... 1363  
 Dobeck, G.J. .... 859  
 Dobyns, A.L. .... 1670  
 Dodd, V.R. .... 512  
 Dodlbacher, G. .... 1209  
 Dogan, I.U. .... 2580  
 Doggett, R.V. .... 1620  
 Doggett, R.V., Jr. .... 43, 1456  
 Doige, A.G. .... 1087  
 Dokanish, M.A. .... 1430  
 Dolling, D.S. .... 397  
 Dollman, J. .... 1727  
 Dombrowski, H. .... 611  
 Don, C.G. .... 1882  
 Donald, G.H. .... 523  
 Donaldson, I.S. .... 1288  
 Donath, G. .... 1855  
 Done, G.T.S. .... 1874, 2514  
 Dornfeld, D.A. .... 2060  
 dos Reis, H.L.M. .... 664  
 Douglas, B.E. .... 1493  
 Dousis, D. .... 1541  
 Dover, W.D. .... 1603  
 Dowding, C.H. .... 641, 2311  
 Dowell, E.H. .... 118, 1031, 1102,  
       ..... 1351  
 Downs, B. .... 91, 313  
 Dowrick, D.J. .... 1838  
 Dowson, D. .... 506  
 Drago, R.J. .... 323, 530, 879, 1181  
 Dragonette, L.R. .... 1702  
 Drake, M.L. .... 1339, 1340  
 Dranga, M. .... 2272  
 Dreadin, W.O. .... 2015  
 Drechsler, J. .... 2668  
 Dreher, R.C. .... 308  
 Drenick, R.F. .... 30, 1144, 1198  
 Dresden, J. .... 2585  
 Dressel, P. .... 1424  
 Dressman, J.B. .... 603  
 Driels, M.R. .... 1049  
 Driscoll, D.A. .... 1883  
 Drozdol, J. .... 1846  
 Du, J.-s. .... 1870  
 Dubey, R.N. .... 1161  
 Dubik, A. .... 2187  
 Dubowsky, S. .... 2590  
 Dudman, A.E. .... 288  
 Duffett, D.L. .... 475  
 Duffy, J. .... 2636  
 Dufour, A. .... 2581  
 Dufrane, K. .... 2519  
 Duggan, T.V. .... 1719  
 Dugundji, J. .... 67, 2557, 1000  
 Duncan, A.B. .... 591  
 Dungar, R. .... 479  
 Dunham, R.S. .... 2254  
 Dunn, H.J. .... 1752  
 Durham, D.J. .... 678  
 Durrans, R.F. .... 1069  
 Dutta, P.K. .... 1179  
 Dyrdahl, R. .... 2287  
 Dzygadlo, Z. .... 492, 1455, 2082,  
       ..... 2102

**E**

East, G.H. .... 786  
 Eastep, F.E. .... 286, 929  
 Ebacker, J.J. .... 1859  
 Edelman, S. .... 2012  
 Edgel, W.R. .... 1356  
 Edighoffer, H. .... 477  
 Edighoffer, H.H. .... 1626, 2088  
 Edwards, J.W. .... 1441  
 Edwards, R.G. .... 2046  
 Egbert, D.E. .... 2356  
 Eghtesadi, KH. .... 2174  
 Egolf, T.A. .... 1154, 1228  
 Ehrich, R. .... 702  
 Eichelberger, E.C. .... 1276  
 Eicher, N. .... 1894  
 El-Akily, N. .... 360, 1022, 1498  
 Elchuri, V. .... 2037, 2038, 2040,  
       ..... 2041  
 Eldred, K. .... 919  
 El-Essawi, M. .... 2124  
 El-Hakeem, H.M. .... 1343  
 El-Kashlan, M. .... 2169, 2170  
 Elishakoff, I. .... 978  
 Ellen, C.H. .... 940  
 Elliott, T.W. .... 2238  
 Ellis, D.D. .... 2687  
 Ellison, W. .... 301  
 Ellyin, F. .... 2518  
 Elmadany, M.M. .... 1430, 1850

Elmaraghy, R. .... 395  
 El-Raheb, M. .... 1281, 1940, 1941  
       ..... 1950, 2406  
 El-Sayed, H.R. .... 319  
 El-Shafee, O.M. .... 250  
 Eman, K. .... 2059  
 Emergy, J.D. .... 218  
 Emery, A. .... 2615  
 Emery, A.F. .... 1284, 1285, 2616  
 Endebroek, E.G. .... 467  
 Endo, M. .... 2179  
 Engelbrecht, J. .... 2452  
 Engin, A.E. .... 1007  
 Engin, H. .... 2433  
 England, R.H. .... 2286  
 Engler, A.J. .... 640, 2008  
 Engrand, D. .... 426  
 Ennenkl, V. .... 1290  
 Enochson, L. .... 2649, 2681  
 Enright, W.H. .... 709  
 Epstein, A. .... 268  
 Erdogan, F. .... 1765, 2618  
 Ericsson, L.E. .... 1210  
 Ernoult, M. .... 40  
 Erskine, J.B. .... 676  
 Ertelt, H.J. .... 1084  
 Ervin, R.D. .... 61, 1845  
 Eshleman, R.L. .... 332, 666, 1243,  
       ..... 2017, 2655  
 Essinger, J.N. .... 511  
 Etherington, J.F. .... 2591  
 Etsion, I. .... 336, 959, 2110, 2595  
 Etter, P.C. .... 1569  
 Ettles, C.M.McC. .... 585  
 Evans, J.W. .... 2372  
 Everett, D.H. .... 279  
 Everett, W.D. .... 178, 2235  
 Eversman, W. .... 1959, 1960  
 Everstine, G.C. .... 364  
 Ewins, D.J. .... 203, 554, 952, 1729  
       ..... 2232, 2566  
 Ezzat, H.A. .... 73

**F**

Fahy, F.J. .... 1028, 1918, 1920  
 Falconer, D.R. .... 2053  
 Fancher, P.S., Jr. .... 33  
 Fandrich, R.T. .... 2242

Farah, A.	1928	Fleischer, C.C.	1201	Friedmann, P.	2101
Farassat, F.	311, 931	Fleiss, R.	333	Friesenhahn, G.J.	643
Farassat, R.	1612	Fleming, D.P.	508, 605	Frisk, G.V.	396
Farell, C.	1944	Fleming, J.F.	2120	Frohrib, D.A.	2115
Farmer, M.G.	1458	Flesch, R.	1081	Fryba, L.	12
Favier, D.J.	1624	Fletcher, J.D.	2588	Fujii, K.	1253
Fawcett, J.N.	234, 1817	Flipse, J.E.	1949	Fujii, M.	1649
Fedock, J.J.	2628	Florjancic, D.	228	Fujii, Y.	1648
Fehrenbach, J.P.	1910	Foutch, D.A.	1964	Fujikawa, T.	495
Feiler, C.E.	1861	Fluegge, W.	1003	Fujisawa, F.	445, 1115
Feit, D.	1676	Flynn, D.R.	150	Fujita, H.	2548
Feldmaier, D.A.	2325	Fogelquist, J.	1706	Fujita, T.	1072
Felgenhauer, H.-P.	2218	Fokkema, J.T.	848, 1303, 1698	Fujiwara, H.	1405
Felippa, C.A.	2256, 2271	Fong, J.T.	1163	Fukano, T.	226
Felsen, L.B.	193, 456	Fonseka, G.U.	2225	Fukuoka, H.	2447
Felton, L.P.	153	Fontanet, P.	913	Fukushige, K.	1291
Fenton, J.	2346	Fontenot, L.L.	2348	Fukushima, M.	2318
Fenton, R.G.	2491	Ford, D.W.	1215, 1443	Fuller, C.R.	1014, 2162, 2609
Fenves, S.J.	2691	Ford, R.A.J.	726	Fuller, H.C.	1633
Ferralli, M.W.	1471	Forell, N.F.	17	Fung, Y.T.	95
Ferrante, M.	559	Forssen, B.	2650	Funk, G.E.	122, 366
Ferry, J.M.	1316	Forward, R.L.	1337, 1338	Furgerson, R.L.	15
Fertis, D.G.	785	Fossman, R.	1475	Furudono, M.	870
Fiala, V.	422	Fost, R.	1727	Furukawa, T.	2405
Ficcadenti, G.M.	1932, 2025	Foughner, J.T., Jr.	1621		
Fick, S.E.	1348	Found, M.S.	2641		
Fidell, S.	1972	Fowler, B.G.	737		
Fiedler, S.	1892	Fox, C.H.J.	435		
Field, J.S.	1726	Fox, D.W.	113		
Fielding, L.	1367	Fox, G.L.	2267	Gabrael, S.A.	2638
Fields, J.M.	941	Fox, M.J.H.	1018, 1335	Gajewski, A.	975
Filippi, M.	1196	Fox, R.L.	703	Galford, J.E.	2316
Filippi, P.	1256	Foxlee, T.F.	2319	Galgani, L.	844, 845
Filliben, J.J.	2425	France, D.	2526	Galkowski, A.	2187
Finch, R.D.	1541	Francher, P.S.	61	Gallo, A.M.	2038, 2039, 2040
Fine, T.E.	2374	Frank, L.J.	1702	Gailop, J.C.	1799
Fink, M.R.	1217	Franklin, R.E.	1504	Gambet, P.S.	1813
Finn, A.E.	510	Frankowi, G.	1730	Gambhir, M.L.	765
Fintel, M.	1195	Frarey, J.	1744	Gandhi, M.V.	1484
Fiorato, A.E.	384	Frarey, J.L.	674, 1748	Ganesan, N.	980, 2141
Fischer, F.J.	1908	Fraser, R.C.	1083	GangaRao, H.V.S.	1570
Fischer, J.	1432	Fraser, W.B.	1055	Gaonkar, G.H.	1866
Fisher, J.W.	238, 1186	Frazier, L.E.	737	Garba, J.A.	48
Fisher, T.A.	1185	Freddi, A.	1721	Garcia-Gardea, E.	2306
Fitzpatrick, J.A.	1288	Freedman, A.	105	Gardner, T.G.	1466
Fjorkman, M.	52	Freiberg, R.	2243	Garg, D.P.	36, 1429
Flack, R.D.	72, 493, 500, 869 1406, 1813, 2050	Freund, L.B.	2636	Garg, S.C.	1627
Flamand, L.	2112	Frey, J.H.	1796, 1797, 1798	Garg, V.K.	1561
Flax, L.	148	Friant, C.L.	1348	Garner, D.R.	581, 2109
Fleeter, S.	281	Fricke, H.	520	Garrison, C.J.	2072
		Fricker, A.J.	2299	Garro, A.	6, 7

**G**

Gasch, R.	1805	Gliebe, P.R.	1211, 2047	Gregory, D.L.	683
Gasparini, D.A.	829, 1990	Glynn, C.C.	2411	Greif, R.	746, 920, 1203, 2553
Gaukroger, D.R.	1139	Godden, W.G.	1279	Greimann, L.F.	1038
Gauthier, R.D.	837	Godel, H.	1459	Gribik, J.A.	2268
Gauvain, J.	267	Godet, M.	2112	Griesbach, T.J.	372
Gaver, D.P.	159	Goedel, H.	1622	Griffin, J.S.	572
Gay, D.	93	Goenka, P.K.	77, 761	Griffin, M.J.	53
Gaylo, K.R.	1470	Goes, M.J.	1530	Griffin, O.M.	127
Gazanhes, C.	151, 1563	Goetz, R.C.	45	Griffin, P.M.	1197
Gedeon, J.	916	Goff, R.J.	1854	Griffiths, I.D.	912
Geering, H.P.	1754	Goglia, P.R.	2036	Grigoriu, M.	1143
Geers, T.L.	1017, 2611, 1982, .....	Gold, P.	284	Grillenberger, T.	369
	2410	Goldberg, J.L.	658	Grinberg, N.M.	2640
Gehien, P.C.	2629	Golden, T.C.	2193	Groenwald, R.A.	188
Gehlen, C.	401	Goldman, S.	1738	Groom, N.	1672
Gehlen, P.C.	119	Goldschmied, F.R.	1427, 1811	Grossi, R.O.	1932, 2025, 2152
Gelos, R.	1932	Goldsmith, W.	638		2153
George, J.	148	Goldstein, N.A.	789	Grossman, D.T.	947
Geradin, M.	198	Göller, B.	263, 1009, 1939	Grossmayer, R.L.	1758, 2260
Gerardi, T.G.	2087	Gong, E.Y.	2285	Groth, K.	2055
Gerken, B.F.	1892	Gonzalez, R.	713	Grove, C.F.	1989
Gergely, P.	27	Good, R.R.	436	Grover, A.S.	1265
Gerharz, J.J.	1991	Goodling, E.C., Jr.	794	Groves, D.	172
Gerhold, C.H.	1614	Goodykoontz, J.	1450	Guan-Qing, C.	370
Gersch, W.	190, 201	Gorman, D.G.	1178	Guenther, D.A.	814
Geschwindner, L.F., Jr.	83	Gorman, D.J.	132, 985	Guenzler, R.C.	216
Ghanaat, Y.	1194	Gorman, V.W.	216	Guex, L.	974
Ghose, A.	1838	Gosele, K.	533	Guicking, D.	620
Ghosh, D.P.	256	Gossain, D.M.	557	Guigli, J.	349
Ghosh, S.K.	1195	Gossmann, E.	429, 430	Guilbert, M.P.	1662
Giacofci, T.A.	2167	Gottlieb, H.P.W.	2202	Guild, F.J.	1660
Gibbons, C.B.	596	Gottlieb, J.J.	1051	Guilinger, W.H.	1825
Gibbs, B.M.	106, 1919, 2426	Gould, P.L.	250	Guillien, G.	2341
Gibert, P.	457	Goyder, H.G.D.	1021, 1124	Guins, S.G.	59
Gibert, R.J.	268, 373, 736	Gracewski, S.	2274	Gulati, J.M.	1654
Gibson, W.C.	390	Grainger, H.	2526	Gundy, W.	1835
Gie, T.S.	1841	Grant, R.J.	1478	Gunter, E.J.	71, 315, 499, 509 ..... 1406, 1409, 1523, 2050, 2665
Giergiel, J.	1306	Grape, P.M.	47	Guntur, R.R.	2210
Gill, H.S.	2545, 2546, 2547	Grasso, V.	1182	Gupta, G.D.	194
Gill, K.F.	2346	Gratieux, E.	2340	Gupta, K.K.	1522, 1559
Gillespie, T.D.	2684, 2685, 2686	Graunke, K.	2057	Gupta, K.N.	2204
Gillies, A.G.	2601	Graves, G.A., Jr.	833	Gupta, R.K.	616
Gillies, D.J.	299	Gray, I.	1465	Gupta, S.	2543
Gillies, J.	956	Greathead, S.H.	2507	Gurbuz, O.	788
Ginsberg, J.H.	1696	Green, D.M.	1972	Gusarov, A.A.	2663
Giorgilli, A.	.844, 845	Green, I.	2110	Gutierrez, R.H.	454, 2138, 2152 ..... 2157, 2158
Girhammar, U.A.	597	Green, R.E., Jr.	1348	Guttalu, R.S.	2263
Gjestland, T.	50	Greenan, A.F.	2641	Guyader, J.L.	104
Glaser, F.W.	1413	Greenburg, J.B.	2407	Gvildys, J.	264
Glass, B.	672	Greene, G.C.	1612, 1863		
Glew, T.C.	707	Gregory, R.A.	43		

Gyllenspetz, I.M.	645	Hancock, G.J.	937	Heckl, M.	610, 2535
		Hanin, M.	1220	Hedrick, J.K.	1435, 2497, 2498
		Hanley, M.A.	2368	Heiberger, D.	5
		Hanson, C.E.	919	Heifetz, J.	2172
		Hansen, C.H.	1271	Heilker, W.J.	2412
		Hanson, D.B.	283, 555	Heimann, B.	1634
		Hanson, H.W.	1386	Heining, W.	914
		Hara, Y.	298	Heinrich, J.C.	2030
		Hardegen, H.	1547	Heinzman, J.	498
		Harding, K.G.	1091	Hell, T.	682
		Hare, J.R., Jr.	1215	Hellqvist, K.	2079, 2247, 2248
		Haroun, M.A.	782, 1673	Hemami, H.	2273
		Harris, A.S.	632, 2342	Hemmig, F.G.	929
		Harris, J.R.	1398, 2691	Henderson, G.R.	1733
		Harris, T.	1454	Hendricks, S.L.	223
		Harrison, H.D.	272, 274	Hendrickson, C.	800
		Harrison, I.R.	855	Hengel, M.F.	2074
		Harrison, R.F.	1431	Hensing, P.C.	872
		Hart, G.C.	153, 2062	Hensman, N.	676
		Hartman, W.J.	909	Hentschel, W.	1547
		Hartmann, A.J.	843	Herault, J.P.	1563
		Hartzman, M.	1149	Herbein, W.C.	237
		Hasegawa, T.	1695	Herbert, M.R.	1129
		Hashimoto, P.S.	893	Herman, A.S.	496
		Hashimoto, T.	134	Herman, G.C.	1697
		Haslebacher, C.A.	1570	Heron, K.H.	1139
		Haspel, R.A.	1854	Herrmann, G.	413, 1270
		Hassab, J.C.	2003	Hertzsch, M.	235
		Hasselfeld, D.E.	699	Hess, R.L.	1468, 1573
		Hasselman, T.K.	748, 1425	Hessler, R.O.	1042
		Hassenpflug, H.L.	2050	Heuschkel, J.	258
		Hassett, R.	2198	Hewitt, J.R.	2580
		Hatlestad, B.	706	Heyman, J.S.	432
		Hattori, S.	1072	Heymann, F.J.	128
		Haug, E.J.	2680	Heyse, H.	1736
		Hauser, G.	2658	Hickling, R.	2325
		Hauser, W.P.	2046	Hickman, T.R.	2459
		Hausknecht, D.F.	2229	Hickmann, W.	1092
		Hausz, F.C.	578	Hieber, G.M.	175
		Havens, J.H.	470	Higashi, K.	2297
		Hawkins, N.M.	440	Hill, D.	1266
		Hayashi, Y.	878, 2323	Hill, E.	1326
		Hayashikawa, T.	2122	Hills, S.A.	1088
		Hayduk, R.J.	751, 930, 1873	Hilzinger, J.B.	873, 1175
		Hayek, S.I.	1669	Hindry, A.	793
		Haymann-Haber, G.	2301	Hinton, E.	1135
		Hays, C.O., Jr.	2044	Hirao, M.	2447
		Hazell, C.R.	2156	Hirasawa, M.	29
		Healey, J.J.	239	Hirose, T.	1494
		Heap, N.W.	2000	Hirschbein, M.S.	1412
		Heath, W.G.	1440	Hirschberger, G.	439

Hisa, S.	2582	Hove, D.T.	156
Hitchen, I.R.	446	Howard, G.	1835
Hjorth-Hansen, E.	1191	Howe, M.S.	140, 1968
Ho, Y.S.	318	Howell, A.S.	754
Hoa, S.V.	114	Howell, G.P.	2339
Hoard, R.	2229	Hrovat, D.	2565
Hobbs, J.	520	Hsieh, B.J.	803
Hobson, D.E.	82	Hsieh, R.K.T.	2454
Hedges, D.H.	2511	Hsu, C.S.	2262, 2263
Hoenlinger, H.	1619, 1622	Hsu, S.T.	791
Hoffman, H.	1716	Hsu, T.C.	1251
Hoffmann, A.	267, 736	Hu, A.S.	665
Hofmann, R.	1359	Hu, C.K.	374
Hogge, M.	198	Hu, G.T.	2684, 2685, 2686
Hohman, J.J.	147	Hu, H.-c.	2022
Hollburg, U.	2524	Hu, Y.	2277
Holman, G.S.	365	Huang, C.L.	1935
Holmer, C.I.	128	Huang, H.	362, 2390
Holmes, J.D.	1656	Huang, S.N.	1502
Holmes, M.H.	1267	Huang, T.C.	1128, 1344, 1345, 1346, 1347
Holmes, P.	1062, 1551	Huber, P.W.	2481
Holmes, P.J.	1328	Hudson, J.H.	497
Holmes, R.	213, 487, 584, 871, 2633	Hudspeth, R.T.	838, 2072
Holt, J.	1342	Huey, D.C.	2652
Holzlöhner, U.	252	Hughes, P.C.	461
Honda, Y.	2332	Hughes, R.	2459
Honlinger, H.	1459	Hughes, T.J.R.	469, 1134
Hooker, R.J.	309, 1725	Huguenin, H.	169
Hoover, J.	598	Hugus, G.D., III	1722
Hoover, W.R.	2045	Huissoon, J.P.	1178
Hopkins, D.M.	1339	Hulbert, G.	2614
Hopkins, G.R.	790	Humar, J.	2392
Horak, D.	1434, 1435	Hundal, M.S.	214, 1565, 2095
Hori, K.	2447	Hung, N.X.	1282
Hori, Y.	588, 2570	Hunt, D.L.	1104
Horikoshi, C.	1075	Huntley, I.D.	135
Horn, A.	1847	Hurst, C.J.	1035
Horner, G.C.	1875	Huseyin, K.	1395, 2479
Horonjeff, R.	1972	Huston, R.L.	840, 1060, 1491
Horowitz, R.	1548	Hustrulid, W.A.	254
Horsager, B.K.	18	Hutchins, C.M.	2648
Hortel, M.	2302	Hutchinson, J.R.	2132
Horvay, G.	120, 121	Huttelmaier, H.P.	246
Hoshiro, T.	321, 2305	Hutton, P.H.	444, 1751, 2475
Hothersall, D.C.	2073	Hwang, C.	465, 1458, 2357, 2485
Hoto, H.	1649	Hwang, R.-Y.	2485
Hotz, E.R.	2085	Hyer, M.W.	967
Houjohn, H.	330		
Housner, G.W.	782		
Housner, J.M.	1626	Ianniello, C.	629
		Ibáñez, P.	1835
		Iboshi, N.	2344
		Ibrahim, I.M.	1928
		Ibrahim, S.R.	679, 2279
		Ibrahim, Z.N.	2638
		Ichinomiya, O.	1926
		Idczak, W.	2145
		Idelsohn, S.	198
		Igra, O.	1708
		Iguchi, M.	918, 1828
		Iida, H.	1168
		Ikari, H.	1262
		Ikeda, T.	1403, 1407
		Ikeuchi, K.	1237
		Ikui, T.	1295
		Ilgmann, W.	1878
		Imai, T.	445
		Imezawa, K.	330
		Inagaki, S.	393
		Inagawa, M.	1844
		Ingard, K.U.	1511
		Inger, G.R.	1323
		Inman, D.J.	1376, 2208
		Ino, T.	2533
		Irie, T.	92, 337, 358, 768, 1261, 1262, 1917, 2143, 2393
		Irretier, H.	1931
		Irving, H.M.	883
		Irwin, A.W.	2349
		Isakower, R.I.	857
		Isenberg, J.	852
		Ishida, K.	328, 329
		Ishida, Y.	1403, 1407
		Ishiguro, N.	495
		Ishihara, A.	878
		Ishizaki, T.	361
		Ishizawa, K.	2297
		Isom, L.E.	1537
		Isono, H.	958
		Israeli, M.	2255
		Issid, N.T.	2130, 2131
		Issler, L.	369
		Ito, M.	495
		Ito, Y.M.	2286
		Itoh, A.	359
		Itou, S.	1383, 2223

Ivey, E.W.	1230	Jenny, R.	516	Kagan, R.	592
Iwadate, T.	1832	Jensen, J.J.	863	Kagan, V.	592, 599, 600
Iwan, W.D.	1657, 1898	Jepson, D.	873, 1175	Kagotani, M.	321
Iwasaki, F.	2564	Jewell, R.E.	565	Kagotani, T.M.	2305
Iwatsubo, T.	604, 1365, 1408	Jeyapalan, R.K.	1047	Kaiser, J.E.	1035
Iyengar, K.J.	1934	Jindai, K.	2564	Kaisi, M.S.	2594
Iyengar, N.G.R.	998	Jirsa, J.O.	2133, 2589	Kaji, S.	2567
Iyer, K.M.	2612	Jizaimaru, J.	2375	Kajio, Y.	2503
Izor, R.C.	734	Joachim, C.A.	2470	Kajita, T.	777, 988
<b>J</b>					
Jach, K.	2187	Joe, B.W.	540	Kakehi, Y.	2564
Jäcker, M.	2528	Johannes, J.D.	574, 1474	Kaldas, M.M.	986, 2154, 2155
Jackson, C.	514, 1739	John, A.J.	1633	Kalev, I.	1566, 2221
Jackson, J.E., Jr.	2188	Johns, D.J.	972	Kalinowski, A.J.	630, 1150, 2258
Jackson, W.J.	2641	Johnson, C.D.	556, 1768, 2126	Kaliszer, H.	2664
Jacobs, L.J.M.	1206	Johnson, E.H.	1458, 2357	Kalumuck, K.M.	2481
Jacobs, P.A.	159	Johnson, E.R.	348, 976, 2137	Kalyanasundaram, N.	1043, 1044,
Jacobson, M.J.	2343	Johnson, J.H.	669		1374
Jaeger, L.G.	1963	Johnson, L.	748, 1106	Kamada, O.	2308
Jahnele, H.A.	2355	Johnson, M.A.	2465	Kamat, M.P.	402, 474
Jahsman, W.E.	837	Johnson, M.R.	274	Kameda, H.	798
Jain, A.	2616	Johnson, W.	291, 292, 293, 874, ... 1152, 1153, 1176, 1226, 1388, ... 1389	Kameoka, K.	1096
Jain, R.K.	271	Johnston, G.W.	1630	Kaminskas, V.	595
Jain, V.K.	859	Johnston, J.P.	1952, 2420	Kaminski, E.	305
Jaini, C.K.C.	1556	Johnston, M.E.	568	Kan, C.L.	2537
Jainski, Th.	2530	Joly, R.	273	Kan, H.P.	2439
Jakobsen, J.	1352	Jones, A.V.	424	Kan, K.	2381
Jalloh, A.	1375	Jones, C.T.	34	Kana, D.D.	25
James, A.	908	Jones, D.I.G.	579, 2100, 2632	Kanei, T.	1024
James, P.K.	296	Jones, H.W.	634	Kaneko, Y.	1261
James, R.J.	2254	Jones, I.S.	2502	Kanezaki, K.	126
Jan, C.M.	81	Jones, J.H.	565	Kania, N.	2055, 2056
Janach, W.	974	Jones, N.	664, 1040	Kannatey-Asibu, E., Jr.	2060
Janisch, H.	1114	Jones, R.E.	2139	Kannel, J.W.	1108
Janotkova, E.	1290	Jones, R.R.K.	1877, 2073	Kanninen, M.F.	119, 401, 2629
Japs, D.	1651	Joshi, S.	1672	Kano, M.	1112
Jarzynski, J.	2459	Jovanovic, D.	2075	Kantola, R.A.	1414
Jayaraman, K.	1234	Jovanovski, J.	2488	Kao, R.	123
Jaynes, E.T.	1507	Juarbe, F.M.	2368	Kao, S.	2071
Jean, M.	1378	Judd, J.E.	303	Kaplan, B.Z.	2032
Jeandidier, C.	267	Juneja, B.L.	350	Kaplan, S.	260
Jeanpierre, F.	268, 736, 2070, ... 2171	Junger, M.C.	866	Kapoor, P.	1933
Jemelka, P.	2409	Junkins, J.L.	295	Kapoor, S.G.	2306
Jendrzejczyk, J.A.	377, 1678	Jurevičius, J.	593	Kapur, A.D.	1265
Jennings, A.	922	Jutras, R.	1727	Karchmer, A.	1451
Jennings, P.W.	2502	K		Kareem, A.	1589
		Kachadourian, G.	206, 207	Karl, F.	1583
				Karlekar, B.V.	1020
				Karmakar, S.B.	192
				Karmel, A.	1437

Karnopp, D.	1755	Kenworthy, M.	34	Klumpers, K.J.	2105
Karpel, M.	1452	Keowen, R.S.	1363	Knauer, H.S.	149
Kascak, A.F.	222	Keresztes, A.	916	Knisely, C.W.	1327
Kasai, K.	2564	Kerle, H.	1558	Knobelock, J.	2322
Kassawara, R.P.	734	Kerschen, E.J.	1952, 2047, 2420	Knott, P.R.	1859
Kasser, J.	1111	Kerstens, J.G.M.	2483	Knox, K.J.	2544
Kasuba, R.	2372	Keskar, D.A.	1221	Knudson, H.T.	537
Katayama, K.	1059	Kessler, F.M.	2182	Ko, P.L.	133
Katayama, T.	1059	Khalil, T.B.	2091	Ko, S.-H.	944, 2151, 2422
Kathiiresan, K.	836	Khan, M.A.	1750	Kobatake, K.	134
Kato, K.	2344	Khandelwal, R.S.	1946	Kobayashi, A.	2615
Kato, T.	2570	Khatib-Rahbar, M.	1833	Kobayashi, A.S.	440, 1284, 1285, 1372, 2616
Katsaitis, S.	1658, 2399	Khorunghin, V.S.	1655	Kobayashi, S.	870
Katto, Y.	1689	Khot, N.S.	1454	Kobler, V.P.	574, 757
Katzenmeier, G.	369	Khurana, O.P.	1734	Kodama, Y.	226
Kauffman, W.M.	536	Kidd, C.C.	1353	Koelle, U.	1634
Kaul, M.	1706	Kidoguchi, H.	1362	Koenigsmann, W.	2373
Kaul, R.K.	86, 413, 1664	Kiefer, R.J.	448	Koga, K.	958
Kausel, E.	884	Kielb, R.E.	110, 1889	Koh, A.-S.	1831
Kavolélis, A.-P.	494, 593, 594, 595, 651, 652	Kienappel, K.	1709	Kohata, H.	2136
Kawabata, N.	2365	Kienholz, D.A.	390, 2126	Kohler, F.	1244
Kawakami, M.	261	Kientzy, D.W.	1129	Koike, T.	798
Kawanobe, O.	775	Kiessling, F.	1803	Koishikawa, A.	134
Kawata, E.	29	Kikuchi, K.	1168	Koizumi, T.	654
Kaye, M.C.	1207	Kikuchi, K.	870, 2533	Kolerus, J.	1109, 1110
Kaynia, A.M.	884, 2561	Kim, C.E.	1750	Kolitsch, J.	185
Kaza, K.R.V.	312, 1889	Kim, C.H.	2500	Kollegger, J.P.	1921
Kedzior, C.T.	188	Kimball, C.E.	2334	Koltzsch, P.	314
Keer, L.M.	388	Kimura, K.	1516	Komatsu, K.	2533
Kehl, K.	1803	Kinh, N.V.	1058, 2205	Konami, S.	1485
Keim, W.	1803	Kinoshita, Y.	1998	Kondo, H.	1275
Kelleher, B.J.	1632	Kinra, R.K.	2417	Kondrat, A.	957
Kellenberger, W.	2506	Kiremidjian, A.S.	1837	Kon-no, A.	412, 414
Keller, A.C.	677	Kirk, C.L.	804	Konstantinidis, S.	412, 414
Kelly, B.E.	2116	Kirk, R.G.	523, 1644, 2596	Konuk, I.	262
Kelly, J.J.	2173	Kirkham, W.R.	271	Koopmann, G.H.	896
Kelly, J.M.	32, 1142, 2097, 2098	Kirkhope, J.	523	Koori, Y.	1030, 1174
Kelly, S.G.	1053	Kirsch, P.A.	1837	Kopp, J.W.	29
Kempe, G.	289	Kistler, B.L.	2355	Koppe, R.	641, 642
Kempner, L., Jr.	534	Kiureghian, A.D.	1284	Kopriva, Z.	1706
Kempton, A.	1581	Kivity, Y.	821, 799, 1712	Korb, J.	1764
Kennedy, D.A.	2654	Kiyono, S.	2255	Korkosz, G.J.	1852
Kennedy, J.B.	1934	Kliem, W.	762, 1648	Korn, J.	2253
Kennedy, M.	85	Klein, R.H.	204	Kossa, S.S.	1753
Kennedy, R.P.	28, 260	Klepper, D.L.	1232	Kos, M.	1647
Kennedy, W.	1178	Klimov, D.M.	245	Kosábek, J.	249
Kennedy, W.C.	1418, 1470, 1512	Klingenberg, R.	2477	Kosinski, W.	1321
Kenny, R.A.	165, 1524	Klinger, F.	2568	Kot, C.A.	2634
Keowen, R.	1835	Klompas, N.	1885	Kotera, T.	801, 803
Kenttala, J.	60		438	Kounadis, A.N.	219, 452, 1173
			2363		1248, 1526

Kovac, J.	1469	Kussmann, A.	949	Lawrence, G.J.L.	2418
Kovac, J.G.	538	Kuttler, J.R.	1263	Lawson, P.	622
Koval, L.R.	1015, 1016	Kuttruff, K.H.	2429	Lazopoulos, C.A.	1692
Kovats, Z.	66, 759	Kwak, Y.K.	276	Lazzeri, L.	1393
Koyama, T.	321, 2305	Kwok, K.C.S.	1824	Lea, J.A.	1501
Kozluk, M.J.	367	Kyomen, S.	1496	Leadbetter, S.A.	566
Kragh, J.	1974			Leader, M.E.	493, 1406
Krajcinovic, D.	2225			Leandre, J.	151
Krämer, E.	1804, 2052, 2527			Lee, C.S.	581
Kramer, K.	220			Lee, G.F.	1528
Krasnicki, E.J.	657, 2209			Lee, J.	1318
Krause, H.	2099	Laananen, D.H.	1222, 1223	Lee, J.K.	2361
Krauss, A.	289	Lacey, J.A.	1418	Lee, L.H.N.	366, 368, 796, 1665,
Krauter, A.I.	2574	La Diega, S.N.	1182		1761, 2455
Krenevičius, A.	599	Lagnese, T.	2100	Lee, M.Z.	379
Krenk, S.	2400	Lai, J.C.S.	2201	Lee, S.Y.	2084
Kress, R.	1562	Lai, K.M.	834	Lee, T.H.	22
Kretschy, M.	317	Lai, S.P.	1192	Lee, T.W.	854
Krieg, R.	263, 1939, 1943, 2165	Lakshminarayana, B.	2051	Lee, W.H.	755
Krinsky, S.	1483	Lalanne, M.	212	Lees, A.W.	2586
Krishna, R.	296	Lallman, F.	1685	Lehmann, D.	1886
Krishnan, V.	1461	Lalor, M.J.	172	Lehringer, F.J.	621
Kristiansen, U.R.	1050, 2362	Lamb, P.	137	Leie, B.	489
Krodkiemski, T.	501	Lamb, R.A.	2625	Leipholz, H.H.	2310
Krodkiewski, J.	2515	Lambert, D.R.	926	Leis, B.N.	2519
Krousgill, C.M., Jr.	1691	Lambert, N.	1151	Leissa, A.W.	100, 101, 617, 865,
Krulick, T.G.	2689	Lambert, R.G.	659, 2220		1259, 2158, 2361, 2612
Krumm, H.	876	Lamure, C.	911	LeMay, I.	834
Kryter, R.C.	802	Lancey, T.W.	763	Lena, A.L.	2468
Kubo, A.	762	Landadio, F.J.	503	Leon, R.L.	189
Kuehn, M.	1622	Landram, C.S.	2285	Leonard, J.W.	838, 2072, 2380
Kuemmerle, W.	1583	Lanes, R.F.	1813	Leonavicius, M.-K.	599, 600
Kufert, D.	800	Lang, W.W.	1574	Leoni, R.D.	1227
Kuhn, M.	1459	Langdon, F.J.	912	Leontaritis, I.	1775
Kuhl, W.	613	Langen, I.	728	Lepelletier, T.G.	2314
Kulak, R.F.	2673	Langrana, N.A.	854	Lepik, Ü.	1900
Kulkarni, S.V.	2103	Lapini, G.L.	2573	Lepor, M.	1449
Kumar, B.	833	Larson, R.S.	1865	Lerchbäcker, A.B.	434
Kumar, R.	2161	Larsson, N.	1525	Lesueur, C.	104, 108
Kundert, W.R.	1732	Lashkari, M.	2619	Leu, M.C.	1479
Kunow-Baumhauer, A.	1004	Lau, M.G.	1029	Leung, A.Y.-T.	1379
Kunzel, V.	1184	Lataillade, J.L.	1800	Leung, Y.T.	1136, 1914
Kuo, C.-P.	2678	Laudadio, F.J.	725	Levek, R.	1147
Kurajian, G.M.	164, 1564	Laudiero, F.	88	Levek, R.J.	1224
Kurakake, Y.	298	Laura, P.A.A.	115, 454, 1905,	Leventhal, H.G.	1231, 2174
Kurkov, A.P.	2360		... 1932, 2025, 2138, 2152, 2153,	Levin, H.A.	891
Kurra, S.	633		... 2157, 2158	Levine, H.S.	2081
Kurtz, R.J.	444, 2475	Laurenson, R.M.	415	Levine, N.	1876
Kurz, K.	1842	Laurent, K.J.	1694	Levinson, M.	997, 1899
Kushner, A.S.	2254	Laurie, E.J.	1869	Levshin, A.L.	389
Kushner, F.	224, 670	Law, R.	1164	Levy, B.S.	2352

Levy, G.	1289	Louis, D.	426	McQueen, D.H.	392
Lew, H.S..	1158	Love, W.	2615	McVerry, G.H.	244
Lewiński, P.	2408	Love, W.J.	1284, 1285, 2616		
Lewis, C.H.	53	Lovegrove, J.M.	2644		
Lewis, D.W.	498, 586	Lovell, E.G.	1280	<b>M</b>	
Lewis, P.T.	908	Lozzi, A.	2554		
Li, C.-H.	2577	Lu, S.C.	365		
Li, C.S.	2250	Lu, S.Y.	2608	Ma, D..	1601
Li, D.F.	69, 76, 2584	Lucchesi, M.	398	Ma, L.N.	2652
Li, G.-h..	2424	Luco, J.E.	1828	Ma, T.-C.	1086
Li, Q.-H.	2049	Ludwig, A.	1943	Ma, Y.-C.	2451
Li, T.F.	1948	Ludwig, D.	1640	Maattanen, M..	1604
Liao, Y.	851	Luh, G.G.-F..	2466	Mabry, J..	1629
Libby, M..	704	Luhrs, R.A.	747	MacAdam, C.C..	61, 2684, 2685,
Liber, T.	548	Luisoni, L.E.	115		2686
Librescu, L.	1666	Luk, C.H..	1948	MacBain, J.C..	1091
Lichtenberg, G..	1808	Luk, Y.W..	856	Macco, A.	749
Lieb, B.W..	346	Lukaszek, T.J.	1529	Mace, B.R..	990, 991, 992, 993
Lim, S.P..	1010	Lund, J.W..	580, 2106, 2517	Mack, R.J..	1453
Lin, C.C..	1948	Lunden, R..	977	Mackenzie, R.K..	1958
Lin, C.J.	1273	Lundgaard, B..	704	Mackertich, S.S..	1669
Lin, C.-W..	1384	Lundin, K..	247	MacLaughlin, T.F..	2328, 2330
Lin, H.-C..	1679	Lundsager, P..	1888	MacNeal, R.H..	408
Lin, I.-F..	58	Lung, R.H..	2313	Macpherson, M.K..	396
Lin, I.-J..	440	Luongo, A..	84, 963	Macvean, D.B..	160, 275
Lin, W.H..	345, 1911	Lutes, L.D..	827	Madden, R..	538
Lin, Y.K..	772, 1822	Lybas, J.M..	1962	Madigosky, W.M..	1528
Lindberg, H.E..	637, 1421	Lyengar, K.T.S.R..	1260	Maeda, K..	1645
Linlecki, A..	2356	Lysdale, C.A..	1097, 1098	Maeda, T..	1485
Lippmann, S.A..	2359			Maestrello, K..	774
Listvinsky, L..	2172			Maestrello, L..	1966
Little, A.D..	2653			Magnuson, C.F..	917
Little, L..	853			Magrans, F.X..	1971
Littlewood, P..	2523			Mahalingam, S..	160, 2631
Livolant, M..	267, 268, 736, 2070, 2171	McCafferty, G.P..	904	Mahoney, J..	2342
Llorente, C..	806	McCallion, H..	2579	Mahn, D.A..	443
Lo, K.K..	2222	McCann, M.W..	823	Mahoney, J.B..	791
Loceff, F..	684, 1384	McCauley, E.W..	365	Maidanik, G..	979, 2142, 2677
Loden, W.A..	1954, 2080	McConnell, K.G..	1723	Majette, M..	1549
Loewenthal, S.H..	2303, 2304	McCormick, D..	2672	Majima, Y..	1272
Loewy, K..	1482	McDaniel, O.H..	781	Majumdar, B.C..	78
Loh, H.T..	1497	McDiarmid, D.L..	1720	Majumdar, S..	1600
Loiseau, H..	437	McDonald, J.F..	1512	Makarewicz, R..	1310
Loken, A.E..	1912	McGary, M.C..	1542	Makay, E..	3, 839, 1416, 1538
Longmore, D.K..	1025	McIntosh, J..	2011	Makdissi, J..	2578
Loo, M..	758	McKevitt, W.D..	2192	Malanoski, S.B..	522
Lotitz, D.W..	1578	McMaster, W.H..	2285	Malarmey, C..	2341
Lottati, I..	2035, 2556	McMichael, J.M..	2654	Maleci, G..	554
Lotze, A..	938, 1623	McMillan, J..	1504	Malkin, S..	1482
Lou, Y.K..	1949	McNab, A..	1514	Malkus, D.S..	453, 2478
		McNiven, H.D..	1039	Mallik, A.K..	1023, 1903, 2384

Mallikarjunarao, C.	33	Mathews, F.H.	2245, 2246	Merced, V.S.	1411
Mallory, W.R.	1537	Mathewson, K.J.R.	65	Mercer, F.T.	1728
Manfrida, G.	760	Mathiassen, S.	1912	Meredith, D.	2125
Mangiarotti, R.A.	2337	Mathieson, T.A.	188	Merker, H.J.	2104
Manner, A.	37, 928	Matsuda, T.	328, 329	Merriman, T.	1108
Manolescu, N.I.	2272	Matsuhsia, H.	2332	Merritt, P.	287
Manolis, G.D.	2024	Matsumoto, H.	338, 355, 359, 1680	Merritt, P.H.	556, 668
Manolis, G.M.	2065	Matsu, H.	1853	Mertens, H.	570
Mansouri, T.A.	733	Matsu, K.	1295, 1853	Mescall, J.F.	692
Marcotte, P.P.	65	Matsushita, O.	870, 2533	Messick, W.	2250
Marczak, J.	2187	Matsuura, T.	2582	Mettler, E.	2436
Maresca, C.	1624	Matsuzaki, Y.	2146	Metzger, W.W.	2089
Margolis, D.L.	462, 841, 1380, 2565	Matsuzawa, K.	1695	Meyer, G.	187
Margulies, G.	421	Maurer, J.K.	1185	Meyer, K.J.	1821
Mariamy, Y.A.	2598	Mayes, I.W.	2520	Meyer, W.	1611
Maricic, N.L.	752	Maxwell, D.E.	2540	Meyer, W.L.	1505
Markert, R.	491, 1807	Maxwell, J.H.	1360	Miao, W.	284
Marks, W.L.	1987	Maxwell, T.L.	2411	Michelberger, P.	916
Markus, Š.	341, 1250, 1783, 2395	May, D.N.	807, 808, 809, 810, 811	Midha, A.	1489, 2296, 2378
Marley, S.J.	577	Mayes, R.L.	2309	Mielcarek, A.	1849
Maroney, G.E.	546	Mazumdar, J.	1266	Mikulcik, E.C.	742
Marsh, H.	589	Meachum, T.R.	436	Miles, J.H.	2423
Marsh, K.J.	2006	Meacham, W.L.	2292	Miller, C.A.	195, 1779, 2043, 2504
Marshall, A.	82	Mead, D.J.	1725	Miller, D.M.	2394
Marshall, L.G.	245	Medaglia, J.M.	626	Miller, J.C.	1232
Marshall, P.W.	1837	Medearis, K.	1415	Miller, J.G.	1507
Marshall, R.L.	1035	Medwin, H.	1703	Miller, L.G.	216
Martelli, F.	760	Meeker, D.B.	567	Miller, R.E.	343
Martin, D.J.	886	Meggitt, D.J.	2119	Miller, R.K.	2446
Martin, F.A.	581, 2109	Mehta, N.C.	2351	Miller, R.N.	835
Martin, H.R.	1501	Mei, C.	41, 285, 1218	Miller, V.R.	2085
Martin, R.M.	1612	Meinke, P.	1849	Miller, W.R.	1446
Martin, W.W.	1836	Meier-Dornberg, K.E.	687	Mills, G.R.	1458
Martinek, F.	2217	Meieran, H.B.	258	Milsted, M.G.	972
Martinez, P.A.	1363	Meirovitch, L.	1125	Mindle, W.L.	970
Martynyuk, A.A.	1377	Melbourne, W.H.	1824	Mindlin, R.D.	107
Maruyama, K.	1926	Meldrum, B.H.	658	Minkenberg, H.L.	1841
Marynowski, K.	501, 2515	Melke, J.	1851	Mirandy, L.	564
Masri, S.F.	2598	Meller, E.	2080	Mirick, P.H.	1585
Marzok, U.	650, 1776	Mellingen, K.	706	Mirow, H.J.	2010
Mas, C.	1980	Meltzer, G.	297, 2353	Miserentino, R.	566
Masao, T.	29	Melvin, J.W.	1573	Mishra, A.K.	590
Maslen, K.R.	1531	Melzig-Thiel, R.	297, 2353	Miskevics, A.J.	1077
Mason, D.R.	561, 562	Mendelsohn, D.A.	388	Misovec, A.P.	2081
Masri, S.F.	1488, 1907, 2387	Mendenhall, M.R.	1567	Mital, N.K.	1653
Massoud, M.	1571, 2358	Menge, C.W.	149	Mitchel, B.J.	405
Masterson, D.M.	1854	Mengi, Y.	1039	Mitchell, L.D.	2493
Matheson, M.J.	1656	Mengle, V.G.	485	Mitchell, J.S.	695, 1748
Mathew, J.	2183	Mente, L.L.	1730	Mitchell, L.D.	856, 1819, 2676
Mathews, D.C.	39			Mitchiner, R.G.	2493

Mitropolsky, Y.A.	1377	Morton, D.K.	623	Nagaya, K.	354, 618, 1924, 1925,
Miura, F.	1826	Morton, P.G.	669		2371
Miwa, M.	721	Moses, N.M.	1858	Nagi, A.	2045
Mixson, J.S.	1616, 1863, 2338	Mota Soares, C.A.	982	Nagpal, V.	763
Miyake, Y.	2365	Mote, C.D., Jr.	1479	Nagpal, V.K.	1344, 1345, 1346,
Miyashita, M.	1170, 1404	Mruk, G.K.	1361		1347
Mizoguchi, K.	1405	Mucino, V.H.	2490	Nakagaki, M.	836
Mizoguchi, T.	2375	Mueller, M.	1583	Nakagawa, M.	2179
Mizusawa, T.	777, 988	Mueller, P.	806	Nakagawa, T.	2503
Mizutani, H.	325, 2369	Mufti, A.A.	1963	Nakahara, I.	338, 355, 359, 1680
Mizutani, K.	721, 2295, 2521	Muhe, P.	1432	Nakai, M.	1307
Mlakar, P.F.	639	Mulcahy, T.M.	1077, 1678, 1737	Nakajima, K.	1096
Mochizuki, H.	1295	Mulholland, K.A.	2011	Nakamura, A.	2147
Model, N.	1634	Müller, A.	1809	Nakamura, K.	1844
Modrey, J.	1480	Müller, G.	2075	Nakamura, T.	352
Moehle, J.P.	2134	Muller, P.	1767	Nakamura, Y.	961
Moffitt, R.	873, 1175	Müller, R.	1296, 1297	Nakano, M.	1832, 2531
Mohanan, V.	2014	Muller, W.C.	1067	Nakao, Y.	2136
Mohsen, E.A.	13	Munjal, M.L.	1397	Nakayama, I.	2147
Mohsin, M.E.	450	Munson, D.P.	787	Nakra, B.C.	1396, 1884, 2204
Mokhtar, M.O.A.	74	Murase, K.	403	Namba, M.	1291
Molenkamp, F.	655	Murase, Y.	2136	Nánási, T.	1783, 2395
Moll, T.	1619	Murata, S.	2365	Narayan, V.	1117
Molly, J.P.	949	Murga, M.	239	Narayanan, G.V.	199
Molnar, A.J.	484, 2268	Murin, J.	425	Narayanan, S.	1023, 1903, 2384,
Monaco, R.	846	Muro, H.	1645		2602
Mondy, R.E.	1367	Murphy, B.T.	2592	Narita, Y.	100, 101, 1259
Monici, M.	1546	Murphy, C.H.	294	Narui, H.	393
Montgomery, C.	2074	Murphy, R.C.	523	Narumiya, H.	2570
Month, L.A.	406	Murphy, T.W., Jr.	2107	Naruoka, M.	777, 988
Moodie, T.B.	2610	Murray, M.A.	922	Narver, R.B.	893
Mook, D.T.	1063	Murray, M.G., Jr.	334, 513	Nash, P.T.	619
Moon, F.C.	342	Murray, P.D.	2311	Nash, W.A.	783
Moore, E.L.	463	Murray, R.C.	891	Nassir, A.	1884
Moore, J.W.	498	Murrill, R.J.	1585	Nath, B.	1595
Morand, H.	858	Murthy, V.R.	954	Nath, J.H.	2380
Moreadith, F.L.	24	Murty, A.V.K.	4	Natke, H.	2550
Morfey, C.L.	2339	Muser, D.	949	Natke, H.G.	2501
Morgan, P.L.T.	1201	Muszynska, A.	2100	Naudascher, E.	1836
Morgner, W.	1736	Muto, T.	1024, 2417	Naughton, T.J., Jr.	2350
Mori, A.	965	Myers, A.W.	553	Nayfeh, A.H.	1032, 1035, 1053,
Mori, H.	1237	Myrhaug, D.	973		1063, 2173
Morino, L.	417, 476, 714	Na, T.Y.	164, 1564	Neathery, R.F.	155
Morita, S.	177	Nagai, M.	918	Nebelung, C.W.	2258
Miriya, S.	2308	Nagamatsu, A.	878, 2463	Neemeh, R.A.	1519, 1981
Morris, B.R.	288	Nagashima, T.	2344	Nefske, D.J.	2470
Morris, G.J.	1871			Neilson, H.C.	364
Morris, H.D.	668			Neise, W.	1174, 1784
Morris, I.R.	1257			Neishlos, H.	2255
Morrison, H.F.	2068			Nelson, F.C.	2199
Mortelmans, F.K.E.C.	2536			Nelson, H.D.	1410, 2292

N

Nelson, R.B.	2286	Noor, A.K.	2265, 2283	Oliferuk, W.	1235
Nelson, R.L.	1160	Noordzij, L.	2333	Oliva, M.G.	2135
Nelson, T.A.	891	Nordell, W.J.	2119	Oliver, M.J.	1088
Nerz, K.P.	1111	Nordenson, G.J.P.	17	Olivieri, M.	1823
Nesbit, E.E.	694	Nordmann, R.	316, 2583	Olsen, J.J.	286
Neubert, V.H.	767, 2092, 2599	Norris, A.N.	2473	Olson, D.	787
Neuerburg, W.	1593, 1999, 2538	Norris, T.R.	1472	Olson, M.D.	2512
Neumann, R.	648	Norton, M.P.	2416	Oltmann, R.	2278
Neuts, M.F.	1520	Norwood, C.J.	91	O'Massey, R.C.	1462
New, R.W.	231	Novak, M.	732, 793	Omata, S.	177
Newman, J.C., Jr.	1994	Novomestky, F.	1144	On, F.	564
Newmark, N.M.	16	Numrich, S.K..	1702	Ono, K.	442
Newton, R.E.	471	Nystrom, P.A..	311	Ono, T.	720, 1096
Nezu, K.	1362			Ookuma, M.	2463
Ng, K.W.	1487			Opilski, A.	1977
Nhuan, P.D.	10		<b>O</b>	Oppenheim, I.	800
Ni, C.M..	2354			Oppenheim, I.J.	1821
Niblett, L.T.	1663			Orey, S.	1550
Niblett, T.	1247	Oates, J.B.	2164	Ormerod, M.	288
Nicholas, J.C.	315, 523, 586, 1644, 2596	Obernhuber, P.	400	O'Rourke, M.J.	255
Nicholson, D.W.	2196	Oblizajek, K.L.	2359	O'Rourke, T.D.	797, 2419
Nickerson, D.B.	473	Ochi, M.	1695	Orsi, A.P.	230
Nicolae, V.	431	Ochiai, S.	29	Osborn, J.	915
Nielsen, H.B.	2517	Oda, S.	327, 2367	Osman, M.M.	807, 808, 809
Nigam, N.C.	1946	O'Donnell, M..	1507	Ostrem, F.E..	635
Nigh, G.L.	2512	Oesterle, R.G..	384	Ostrowski, P.P.	1519, 1981
Nigul, U.	1552	Oey, K.T..	404	Ota, H.	721, 2295, 2521
Nijs, L.	1206	Oftedal, G..	50	Otomo, K.	966
Nikiforuk, P.N.	1333	Ogendo, J.E.W..	972	Otsuki, Y.	1253
Nikolaisen, J.L.	871	Ogimoto, K..	381	Ottens, H.H..	1079
Nilrat, F.	1711	Ohanehi, D.C..	1419	Ottl, D..	2207
Nilsson, A.C.	116	O'Hare, J.E..	1090	Ousset, Y.	2028
Nintzel, A.J..	690	Ohashi, H..	488	Oviatt, M.D..	2534
Nishi, S..	2179	Ohlrich, M..	923	Owsik, J..	2187
Nishikawa, T.	720	Ohmi, M..	1496	Özgüven, H.N.	1923
Nishimura, T.	403	Ohnishi, K..	1832		<b>P</b>
Nishioka, T.	459, 460, 539, 1130, 1131, 1132, 2637	Ohrstrom, E..	52	Paddy, R.H.	2320
Nishitani, A..	826	Ohshio, Y..	1832	Padgaonkar, A.J..	2329
Nishiyama, T.	2364	Ohya, A..	1253	Padovan, J..	8, 221, 1330, 1801, 1984, 2682, 2683
Nisonger, R.L.	33	Oie, S..	145	Padula, S.L..	774, 1864
Nissim, E.	2035, 2556	Okabe, S..	2061	Paez, T.L..	686, 2249
Niyogi, B.K..	26	Okajima, M..	29	Page, J..	1820
Noah, S.T.	790, 2391	Okamoto, S..	1494	Pagliarini, G..	1013
Nocilla, S.	1770	Okamoto, Y..	355	Paidoussis, M.P..	2130, 2131, 2413, 2415
Noll, T.E..	1458	Okazaki, T..	1680	Pajewski, W..	1998
Nollau, R.	232	O'Keefe, E.J..	14		
Nomoto, H.	1689	O'Keefe, J.V..	2337		
Nonami, K.	1170, 1404	O'Keeffe, J.M..	2651		
Noonan, E.F..	2288	Okumura, M..	261		
		Oldham, D.J..	13, 2000		
		Oledzki, A..	10, 2216		

Pal, N.	376, 792	Peeken, H.	1240, 1650, 1815,	Pirvics, J.	80, 204
Palladino, J.	1580		2525	Pisano, A.D.	705
Palmov, V.A.	1122	Peigney, J.	722	Pisarski, J.J.	525
Pan, C.H.T.	75, 315, 1892, 1893	Peirce, S.	2326	Pissarev, A.	2293
Pancholy, M.	2014	Pekau, O.A.	246, 2189	Pister, K.S.	2176
Pandey, P.C.	2586	Pelton, H.K.	816	Pizzirusso, J.	942
Pandey, R.C.	2296	Pentek, W.	1741	Platzer, M.F.	2201
Pandit, M.	2461	Penzien, J.	773	Plaut, R.H.	.976, 2137
Panek, C.	2200	Pepler, R.D.	2350	Ploch, J.	1762
Panik, F.	1846	Perdikaris, P.C.	27	Plumblee, H.E., Jr.	170, 1615
Panteliou, S.	1171	Peri, M.	1382, 2637	Pocock, R.G.	2418
Pao, J.-H.	2181	Perl, M.	90, 1285, 2615	Pokallus, R.	.439, 2464
Pao, Y.-H.	2402, 2403, 2404, 2443	Perla, H.F.	260	Pokorski, J.	305
Papadrakakis, M.	1119	Pernet, D.F.	1857	Polentz, L.M.	575
Papastavridis, J.G.	2027	Persicke, G.	905	Polhemus, N.W.	2674
Paplinski, A.	2191	Persoon, A.J.	881	Polidorou, G.	749
Pappa, R.S.	2279	Pesko, F.	710	Politch, J.	2647
Pappas, M.	1141	Peters, D.A.	2516	Pollack, M.L.	391, 1499, 1513
Parameswaran, K.	1492	Peters, R.B.	668	Pollard, H.F.	1030
Pardee, W.J.	2448	Peterson, D.	785	Pompoli, R.	1013, 1196
Park, K.C.	712, 1626, 2271	Peterson, E.C.	2322	Ponter, A.R.S.	166
Park, Y.J..	2441	Petrie, A.M.	135	Pook, L.P.	2641
Park, Y.-S.	1723	Pettigrew, M.J.	133	Pope, J.	2325
Parker, G.A.	463	Petruelli, G.	2376	Pope, L.D.	779
Parker, J.V.	892	Petyt, M.	1010, 1068	Pope, R.J.	1100
Parkins, D.W.	1713, 1714, 2108	Peyrot, A.H.	766	Popelar, C.H.	119, 401, 662, 2629
Parkinson, A.G..	700, 2474, 2661	Pfaffinger, D.D..	2284	Popolo, J.	2464
Parnes, R.	1503, 1983	Philippacopoulos, A.J.	30, 154	Popolo, J.J.	439
Parr, V.B..	646	Phillips, G.J.	176	Popov, E.P.	2178
Parrish, B.	1371	Phillips, C.	920	Popov, R.V.	1557
Parszewski, Z.	501, 2515	Phillips, J.W.	374	Popp, K.	550, 1073, 1120
Pasic, H.	1270	Phipps, M.A..	676	Porat, I.	.832, 1904
Paskin, A.	1322	Pi, W.S.	2357	Port, K.F.	1006
Pasquinelli, G..	398	Pianko, M.	282	Porter, C.S.	1597
Passannanti, A.	1182	Pickup, N.	2337	Porter, M.L.	1038
Passerello, C.E.	840	Pielert, J.H.	1399	Potter, R.E.	1854
Patching, C.A..	1085	Piersol, A.G..	936, 1213	Potter, S..	2299
Patel, B.L.	763	Pietruszka, W.D.	1814	Pouyet, J.M..	1800
Patra, M.K..	998	Pifko, A.B..	46, 2190	Powell, C.A..	935
Patrick, R.P.	1316	Pih, H..	2016	Powell, G.H..	2177
Patterson, C.	2588	Pilkey, W.	1543	Pozzi, M..	.551, 899
Paul, D.K.	1135	Pilkey, W.D..	2048	Prabhu, P..	1080
Paul, H.S..	1965	Pillasch, D.W..	1269	Prasad, B..	1659
Paul, R.	1734	Pilz, H..	232	Prasad, M.G..	63
Paul, W..	1208	Pinazzi, F.	38	Prasad, P..	2329
Pavelic, V.	2490	Pinkus, O.	2106	Prathap, G..	.969, 1492, 2382
Pawlowska, V.	853	Pinnekamp, W.	324	Pratt, H.R..	254
Payne, B.W.	288	Pinnington, R.J.	2096	Pratt, T.K..	1986
Payne, J.B..	467	Pinson, L.D..	566	Preisser, J.S..	753
Payne, S.G..	713	Pinzauti, M..	2508	Preuss, R.D..	714
		Piotrowski, J.D..	703	Price, W.G..	.925, 927

Pritz, T.	1071, 2597	Rangacharyulu, M.A.V.	1874	Richter, J.	1514
Proepper, U.	2651	Rangaiah, V.P.	767, 2599	Ricketts, R.A.	1620
Prössler, E.-K.	2281	Rengarajan, A.	1639	Ricketts, R.H.	1456
Pujara, K.K.	350	Ranta, D.E.	2254	Rickley, E.J.	1443
Puch, A.	2290	Rao, A.C.	1556, 1654	Riedel, E.P.	19
Pupeikis, R.	595	Rao, B.V.A.	980, 2141	Riegel, J.P., III	643
Purcell, W.E.	55, 2624	Rao, C.R.A.	2487	Rieger, N.F.	2675
Putman, W.F.	183	Rao, D.K.	1162, 2510	Rienstra, S.W.	1500
Pyke, R.M.	2540	Rao, G.V.	1545	Riffel, R.E.	727
<b>Q</b>					
Quinones, D.F.	2285	Rao, J.S.	256, 2103, 2510	Riganti, R.	419, 1121
Quittner, E.	557	Raous, M.	2029	Rimrott, F.P.J.	1902
<b>R</b>					
Raab, A.	227	Raspet, R.	812	Rippl, A.	1803
Racca, R.	2562	Ratwani, M.M.	2439	Risitano, A.	339
Radcliffe, C.J.	1258	Raty, K.	60	Rivard, A.	2642
Radcliffe, W.J.	1799	Rau, G.	1704	Rivin, E.I.	1417
Rader, D.	480	Ray, A.G.	2670	Rizk, M.N.F.	1928
Radnoti, G.	2252	Ray, H.	1280	Robb, D.A.	999
Radhakrishnan, T.	2476	Rdzanek, W.	1930	Roberts, C.C., Jr.	505
Rae, J.M.	622	Rebont, J.M.	1624	Roberts, J.B.	1066, 1782, 1985, 2033, 2335
Rafie, S.	2449	Rebora, B.	2168	Roberts, W.B.	875
Ragland, C.L., Jr.	2328	Reddy, A.S.S.R.	296	Robertson, J.	1469
Rainey, J.T.	670	Reddy, C.V.R.	980, 2141	Robinson, D.W.	1633
Raju, D.P.	1965	Reddy, J.N.	776, 1929, 1935, 1937, 2149, 2386, 2604	Robson, J.D.	160, 2206, 2630
Raju, P.K.	148, 2650	Reddy, V.S.	776, 2604	Rockwell, D.	1286
RamaChandran, P.V.	1850	Redfern, J.T.	173	Rockwell, T.H.	2007, 2690
Ramaiah, G.K.	111, 1001	Reding, J.P.	1210	Rodal, J.J.A.	663
Ramakrishnan, C.V.	2377	Read, J.W.	28	Rodean, H.C.	1517
Ramamurti, V.	99, 353, 1002, 2148, 2294	Reed, W.	1621	Rodriguez, C.	2168
Raman, A.	4	Reed, W.E.	482, 483	Roeck, G.P.J.M.	2536
Raman, P.V.	987, 1260	Reese, J.M.	2437	Roemer, L.E.	1364
Ramaswamy, S.	1118	Reethof, G.	781, 1486, 1497	Roemer, R.E.	755, 786
Ramamurti, V.	2307	Rega, G.	84, 820, 963	Roessel, J.M.	468, 885
Ramchandani, M.	791	Reich, M.	1149	Rogers, L.	2212
Ramulu, M.	1372	Reid, J.G.	850	Rogers, L.C.	2126
Ranatza, S.	543	Reinicke, W.L.	19	Rohde, D.F.	2625
Rand, D.	1551	Reissland, M.-U.	2078	Rohde, S.M.	73, 257 <sup>1</sup>
Rand, R.H.	406, 1328	Reistad, K.	301	Rohn, D.A.	2303, 2304
Randall, K.E.	1880	Rejf, P.	262	Rohrle, H.	1381
Randall, R.B.	2657	Reneker, D.H.	2012	Rojahn, C.	2062
Raney, J.P.	932, 1212, 1864	Renz, P.	1835	Rokhlin, S.I.	1701
		Rentz, P.E.	2342	Roland, J.	1420, 2175
		Rericha, I.	1209	Romander, C.M.	541
		Reshotko, M.	1451	Ronen, A.	1482
		Retelle, J.P., Jr.	2654	Ronen, T.	1220
		Rezansoff, T.	2589	Ronneberger, D.	1052
		Ribbens, W.B.	2457	Rooke, J.H.	869
		Ricciardiello, L.	38	Rooker, J.R.	1373
		Richard, J.	273, 1249	Röper, R.	1651
		Richards, E.J.	2184	Ropte, E.	1637
		Richardson, J.	2198	Rosakis, A.J.	2636

Roseau, M.	2435	Saff, C.R.	481	Sathyamoorthy, M.	1671
Rosenau, W.	277	Safford, F.B.	688, 2243	Sato, H.	968
Roskam, J.	1034, 1294	Sagner, M.	373	Sato, K.	445, 2308
Ross, C.A.	598, 619	Sahay, C.	1161	Sato, S.	321, 2305, 2332
Ross, C.F.	1975	Sai'd, W.K.	1884	Sato, T.	1112, 1826
Ross, C.T.F.	1006	Saiidi, M.	882, 1915	Satsangi, K.	754
Ross, D.F.	142	Saikudo, R.	1832	Satter, M.A.	628, 1515
Ross, H.E., Jr.	900, 901	Sailors, R.H.	2635	Sattinger, S.S.	667
Rossini, T.	2573	Saito, H.	775, 2129	Satyanaarayana, A.	799
Roszmanith, H.P.	2224	Saito, Y.	654	Satyanaarayana, V.V.	256
Rostafinski, W.	1961	Saito-o, M.	1636	Saul, R.A.	2328
Rott, D.	1991	Sakai, H.	1476, 1887	Sawyer, J.	1625
Roufaeil, O.L.	109, 983	Sakamot, H.	2318	Sayed-Esfahani, R.	2240
Round, D.F.	1709	Sakata, M.	1058, 2179, 2205	Sayhi, M.N.	2028
Roure, A.	1048	Sakata, T.	1922	Sayir, M.	340
Rowbottom, M.D.	2213	Salah el din, A.S.	2644	Sazama, F.J.	2244
Rowell, D.	1427, 1811	Salama, M.	2124	Scala, M.	1393
Roxner, T.	1858	Salamone, D.J.	1409, 1641, 2665	Scalise, D.T.	1279
Rozelle, D.M.	2486	Salane, H.J.	1908	Scarton, H.A.	1418, 1470, 1512
Rubek, J.	266	Salewski, K.	650	Scawthorn, C.	1591
Rubin, M.	538	Salewski, K.-D.	1776	Scedel, W.	124
Rubin, M.N.	627	Salikuddin, M.	170	Schachne, G.L.	558
Ruddy, A.V.	507, 587	Salter, R.J.	2073	Schachenmann, A.	1286
Ruge, P.	2496	Salzwedel, H.	1332	Schade, D.	2020
Ruhl, J.A.	1838	Sampat, P.T.	320	Schafer, B.	962, 1245
Ruhlin, C.L.	43	Samson, A.	1769	Schafer, M.	919
Ruijgrok, G.J.J.	1216	Samueli, H.	1535	Schaller, R.J.	1
RuLiang Wang, L.	795	Sancar, S.	2443, 2444	Schänzer, G.	42
Rungta, R.	2519	Sand, I.O.	973	Scharf, L.L.	1138, 2230
Rupprecht, S.	2492	Sandercock, D.M.	875	Scharton, T.D.	1353
Russell, D.L.	1076	Sandler, B.	1183	Schatte, M.	297
Ryan, R.S.	565	Sandman, B.E.	572	Schauble, C.C.	619
Rybicki, R.	1646	Sandstrom, R.E.	1608	Scheelke, I.	2651
Rybicki, R.C.	1177	Sani, G.	38	Scheithe, W.	1996
Ryder, J.T.	1341	Sankar, S.	114, 2058, 2210, 2211	Schiff, A.J.	738, 1777
Rylander, R.	49, 52	Sankar, T.S.	191, 2058, 2140	Schiff, M.I.	1447
Rymarz, CZ.	2145	Sankewitsch, V.	1635	Schilling, U.	1675
<b>S</b>					
Saadat, H.	1256	Sankey, G.O.	484	Schindwolf, R.	1688
Sachdev, S.S.	557	Sano, M.	1075	Schlegel, V.	1806, 2280
Sachdeva, T.D.	2377	Santana, C.	193, 456	Schmeisser, G.	9
Sachse, W.	2444	Santoboni, S.	907	Schmidt, G.	2021, 2302
Sackman, J.L.	32, 638, 1142	Sanyal, A.	1162	Schmidt, G.S.	1742
Sadek, E.A.	450	Sarfeld, W.	1805	Schmidt, H.	2400
Sadek, M.M.	880	Sarker, P.K.	1933	Schmidt, J.H.	558, 2231
Safak, E.	1964, 2063	Sarmiento, G.S.	115, 454, 2025	Schmidt, K.J.	2239
Safar, Z.S.	74	Sarzyński, A.	2187	Schmidt, W.C.	532
		Sas, P.	1607	Schmitz, F.H.	1225, 1586
		Sasaki, K.	1112	Schneider, J.	2496
		Sasaki, R.	2297	Schneider, R.E.	363
		Sasakura, Y.	2503	Schnenck, E.B.	444
		Sassi, W.V.	1400, 1401, 1402	Schoffler, W.	228

Schofield, C.	1028	Sensburg, O.	938, 1459, 1619,	Shih, Y.	465
Scholl, D.H.	369		1622, 1623	Shih, Y.-P.	2485
Scholl, R.E.	1916	Sentz, R.H.	515	Shilkrut, D.	1684
Schöllhorn, K.	316, 2583	Senuma, T.	2099	Shimizu, M.	261, 545
Schomer, P.D.	1464, 2182	Seppala, S.	37, 928	Shimizu, N.	29
Schott, G.	1718	Serdyuk, V.A.	2640	Shimode, S.	2548
Schrader, K.	307	Sergev, S.S.	1657, 1898	Shimogo, T.	344, 2531
Schapel, H.-D.	2484	Seshadri, T.V.	2077	Shin, Y.S.	1834
Schreiber, E.	1114	Seshagiri, B.V.	1879	Shinohara, Y.	344
Schreiber, U.	741	Seth, B.	186	Shinozuka, M.	798
Schreyer, H.L.	2628	Sethi, J.S.	26	Shiohata, K.	1115
Schricker, V.	1255, 2177	Sethi, V.S.	1734	Shiohato, K.	445
Schröder, A.	741	Sethna, P.R.	1334, 1550	Shipley, S.A.	1838
Schroter, V.	1918, 1920	Severud, L.K.	1502	Shirakawa, K.	1405, 1668
Schuett, D.	1991	Sewall, J.L.	2088	Shirasawa, H.	2375
Schulze, H.	2550	Sexton, J.S.	531	Shirey, D.L.	644, 2245
Schuman, W.J., Jr.	2243	Sexton, M.R.	948	Shivashankara, B.N.	1155, 1390,
Schumann, U.	375, 544, 1602	Seybert, A.F.	1690, 2215, 2228		1613
Schutz, D.	1617	Seznec, R.	1308	Shoji, H.	488
Schutzenhofer, L.A.	565	Shah, A.H.	1498	Sholping, S.	371
Schwabe, J.E.	785	Shah, V.N.	843, 1825	Shoyama, E.	445
Schwager, K.W.	1444	Shaker, B.S.	1064	Shrivastava, S.K.	2480
Schwanecke, H.	70	Shanbhag, R.L.	2602	Shukla, K.N.	2414
Schwartz, E.	570	Shanker, A.	1653	Shuman, R.L.	1358
Schwarz, H.R.	2495	Sharan, A.M.	2058	Shupert, P.T.	537
Schweitzer, G.	2572	Shapiro, W.	79	Shurui, Z.	386
Schwenzfeier, W.	2458	Sharma, C.B.	1011	Shuttleworth, R.	1724
Schwerdtlin, H.	332, 1243	Sharma, J.K.N.	1179	Siddiqui, F.	2120
Schwieger, E.	2002	Sharma, M.G.	2449	Siekmann, J.	1675
Schwieger, H.	611	Sharp, R.S.	701, 1205	Sierakowski, R.L.	152, 598
Scott, J.	564	Sharpe, R.L.	2309	Sievert, W.	693
Scott, J.N.	573	Shatalov, L.N.	2663, 2669	Sigillito, V.G.	113
Scott, R.A.	1086	Shatoff, H.D.	22	Sigbjornsson, R.	728, 1191
Scott, R.F.	1596	Shaw, L.L.	2084	Sigillito, V.G.	1263
Scott, W.E.	411	Shaw, R.P.	86, 996, 1664	Silva, G.	1896
Sears, J.A.	567	Shawki, G.S.A.	74	Silva, J.M.M.	554
Segal, Y.	1012	Shea, R.	692	Silver, W.	2289
Segall, A.	97	Sheinman, I.	609	Silvia, M.T.	1300, 1301
Segel, L.	1845	Shen, S.F.	485	Šimčák, F.	451
Seguchi, Y.	1145	Shen, Y.-p.	2023	Simiu, E.	2425
Seidman, H.	1392	Shepherd, R.	2601	Šimková, O.	341, 1250
Seireg, A.	58, 2093	Sher, L.	287	Simmonds, J.G.	2401
Schwieger, E.	2460	Sheth, P.N.	537, 577	Simmons, H.R.	517
Seireg, A.	2370	Shibata, T.	321	Simmons, J.M.	2201
Sekhar Reddy, B.	117	Shibata, Y.	1075	Simmons, P.E.	2529
Sekiguchi, H.	1096	Shieh, G.P.	1438	Simon, S.	1938, 2438
Sekino, H.	338	Shield, B.M.	1391	Simonian, S.S.	1425, 1773, 1774
Sekiya, T.	1059	Shih, C.-F.	784	Simonis, J.C.	129
Selvadurai, A.P.S.	1936	Shih, T.	772	Simpson, A.	924
Seneny, P.E.	1421	Shih, T.-Y.	2194	Simpson, J.M.	47

Sinai, Y.L.	2421	Sobieczky, H.	1323	Stangl, G.	1432
Singer, J.	1012	Sobieraj, W.	2102	Stanisic, M.M.	1553
Singh, H.	805	Sobol, T.	2428	Stanway, R.	2240
Singh, I.R.	1935, 2386	Soderman, P.T.	2563	Starsmore, N.	895
Singh, M.	743	Soeda, T.	2471	Stathis, T.C.	1233
Singh, M.P.	825	Soedel, W.	63	Stavsky, Y.	2407
Singh, Y.P.	1329	Soenarko, B.	1690	Stecco, S.S.	2508
Singhal, K.	1771	Sofrin, T.G.	39	Stecki, J.S.	1587
Singley, G.T., III	1223	Solecki, R.	351	Steele, C.M.	815
Siorek, R.W.	1473	Sollmann, H.	1577	Steele, C.R.	2270
Šipoš, L.	2366	Solo, V.	711	Steele, G.H.	1103
Sires-Yifat, C.	1835	Somers, C.	2645	Steele, J.M.	2675
Siskind, D.E.	641, 642, 2008	Someya, T.	2582	Stefanini, A.	1546
Sitarek, I.	1235	Sommerschuh, St.	9	Stehlin, P.	472, 1156
Sivák, B.	2366	Sone, T.	1973	Stenander, L.R.	2659
Sivák, J.A.	183	Soni, M.L.	2219	Stepanishen, P.	349
Sivák, M.	2366	Sonin, A.A.	2257	Stephanakis, K.	1563
Skaar, K.T.	750	Sonnenburg, P.N.	576	Stephen, N.G.	964
Skelton, R.E.	461	Sonor, D.E.	64	Stephenson, D.F.	254
Skingle, C.W.	1139	Soom, A.	1501	Stephenson, R.A.	1134
Skinner, M.S.	2097, 2098	Soong, T.T.	830	Sternberg, A.	978
Skop, R.A.	2180	Soovere, J.	680	Stetson, K.A.	855
Skorpik, J.R.	1751	Sorensen, A., Jr.	1475	Stevens, D.G.	571
Skrikerud, P.E.	242, 251	Sorensen, J.P.	202	Stevens, J.A.	363
Skulte, P.	2519	Sorensen, S.	49	Stevens, K.K.	1070
Slazak, M.	98	Southern, I.S.	1812	Stevenson, J.D.	542
Sleeper, R.K.	308	Southgate, H.F.	470	Stewart, D.R.	14
Slocombe, M.D.	2507	Sozen, M.A.	1915	Stewart, N.D.	813
Smalley, A.J.	656, 700, 2474, 2661	Spada, A.J.	789	Stewart, R.M.	1747, 2671
Smallwood, D.O.	2197, 683	Spagnolo, R.	2005	Stewart, W.E.	202
Smeulers, J.P.M.	1687	Spanos, P.-T.D.	280, 898, 1760,	Stoessel, J.	1835
Smith, C.	1835	Sparks, C.P.	897	Stone, B.J.	531, 1239, 2571
Smith, C.C.	276	Spath, W.	1298	Stone, D.H.	2441
Smith, D.M.	2505	Spencer, A.C.	269	Stone, J.R.	1861
Smith, D.R.	517	Spierings, P.T.J.	1848	Stoneking, J.E.	802
Smith, G.C.C.	2037, 2041	Springer, H.	1890	Storment, J.W.	816
Smith, I.J.	729	Spruogis, B.	651, 652	Stott, S.J.	1488
Smith, I.M.	655	Spychala, A.	2145	Strang, J.M.	2319
Smith, J.D.	2251	Sreenivasamurthy, S.	2294	Straub, F.K.	1463
Smith, J.R.	1545	Srinivasan, A.V.	950	Stredulinsky, D.C.	634
Smith, L.G.	2236	Srinivasan, M.G.	2225	Streich, M.	650
Smith, P.W., Jr.	200, 981, 1988	Srinivasan, S.	1734	Strelcyn, J.	844, 845
Smith, R.L.	835	Srinivasan, V.	99, 353, 1002,	Strickland, W.S.	598
Smith, S.	534, 1106		2148, 2307	Strickle, E.	1637
Smith, T.	622	Stachura, V.J.	642, 2008	Strike, W.T.	1090
Smolka, S.A.	714	Stafford, J.R.	2166	Stroud, R.C.	534, 1106
Sneck, H.J.	1883	Stagg, M.S.	640, 641, 642	Strumpfel, H.	1895
Snoeys, R.	1481, 1607	Stahle, C.V.	559	Stuart, R.J.	612
Snyder, W.T.	1054	Stammers, C.W.	1025	Stühler, W.	1802, 1894
Soavi, F.	756	Stange, W.A.	1091	Stussi, U.W.	2409
				Su, T.C.	1945, 1949, 2613

Suarez, J.J.	877	Takahara, S.	96, 2617	Theuerkauf, J.P.	1473
Subrahmanyam, K.B.	2103	Takahashi, H.	1750	Thien, M.D.	2358
Succi, G.P.	931	Takahashi, I.	92, 337, 768	Thomas, D.W.	2472
Sugihara, K.	2323	Takahashi, S.	1268	Thomas, G.B.	2523
Sugimoto, N.	1272, 2605, 2606	Takamatsu, Y.	226	Thomas, H.-J.	489
Sullivan, T.D.	56	Takatsu, H.	261	Thomas, T.J.	1561
Sullivan, W.N.	1578	Takasaki, Y.	29	Thomasson, S.I.	138
Summers-Smith, D.	507	Takatsu, H.	545	Thompkins, W.T., Jr.	2301
Sunada, W.	2590	Takatsu, N.	2308	Thompson, A.G.	54
Sundara Raja Iyengar, K.T.	987	Takeda, K.	1433	Thompson, B.S.	1484
Sundararajan, C.	194, 1283, 1385	Takeda, N.	152	Thompson, D.E.	2051
Sundararajan, V.	2391	Takeda, Y.	358	Thompson, H.J.	1089
Sung, L.	1070	Takeuchi, K.	269	Thompson, I.	1969
Sung, S.H.	2321	Takeuchi, R.	145, 2147	Thompson, J.K.	2227
Sussman, N.E.	207	Takeuti, Y.	2405	Thompson, R.W.	22
Sutcliffe, W.G.	2651	Takezono, S.	126	Thompson, W., Jr.	2437
Suzuki, K.	1268	Tamura, A.	1168, 2522	Thompson, W.E.	653
Suzuki, M.	134, 1750	Tamura, H.	955	Thompson, W.I.	920
Suzuki, Y.	1648	Tanaka, H.	96, 1636, 2617	Thompson, W.I., III	1355
Sváčina, J.	422	Tanaka, K.	412, 414	Thomson, R.G.	45, 1873
Svalbonas, V.	2639	Tang, H.T.	1359	Thomson, R.K.	2275
Svoboda, J.	2211	Tang, S.C.	1127	Thornhill, R.J.	818
Swan, H.W.	478	Tang, Z.-q.	2023	Thurgood, D.A.	2532
Swan, M.A.	912	Tangri, K.	2469	Tietjen, B.W.	1735
Swannell, P.	1772	Tani, J.	352, 2396, 2398, 2603, ....., 2607	Tilly, G.P.	1820
Swanson, S.R.	2226	Tanna, H.K.	1615, 2234	Ting, T.C.T.	1707
Sweet, L.M.	183, 747, 1437	Tanner, A.E.	1223, 2558	Tipton, A.G.	1445
Swigert, C.J.	1337	Tao, K.	126	Tirinda, P.	306, 1235
Swinerd, G.G.	105	Tauffkirchen, W.	1992	Tischler, V.A.	2090
Syamal, P.K.	2189	Tay, C.H.	1913	Tjøtta, J.N.	2430
Syed, A.A.	1088	Taylor, A.D.	1148	Tjøtta, S.	2430
Sylwan, O.	681	Taylor, C.M.	506	To, C.W.S.	1087, 1123
Symonds, P.S.	1315, 1324	Taylor, J.I.	582, 675, 2656	Toda, A.	2323
Szemplinska-Stupnicka, W.	1331	Taylor, M.E.	2418	Todd, M.A.	543
Szenasi, F.R.	521	Taylor, R.B.	284	Tokaji, K.	1717
Szopa, J.	957, 2259	Taylor, R.E.	265, 2317	Toki, K.	1826
T		Taylor, S.M.	51, 817, 934, 2622	Tomassoni, J.E.	906
Tabaddor, F.	2166	Teh, C.E.	995, 2150	Tomizuka, M.	1548
Tabarrok, B.	2491	Temarel, P.	927	Tomlinson, G.R.	1078, 1105
Taber, L.A.	2091	Templin, K.W.	1354	Tondl, A.	410, 1172
Tada, N.	2375	Terada, K.	2564	Tong, P.	746, 1203
Tada, Y.	1145	Terasawa, T.	2129	Tong, Y.L.	724
Tagart, S.W., Jr.	1706	Terauchi, Y.	1649	Tonndorf, J.	1816
Tait, R.J.	2610	Terborg, G.E.	1340	Torres, M.R.	23
Takada, S.	1594	Teschner, W.	2261	Torset, O.P.	1912
Takagi, M.	2533	Tester, B.J.	2234	Torvik, P.J.	660, 1336
Takagi, S.	2434	Thailer, H.	1706	Towers, D.	919
		Thasanatorn, C.	2336	Touratier, M.	1767
		Thatcher, C.	1093, 1094, 1095	Traill-Nash, R.W.	1756
		Theis, K.	1736	Tran, A.D.	2600
				Tran, H.T.	2446

Tran, P.T.	1287	Ueberall, H.	2045	Varpasuo, P.	60
Trankle, T.L.	849	Ueda, T.	2146	Vashi, K.M.	684, 822
Trautmann, C.H.	2419	Ueda, Y.	1710	Vaske, P.	428
Trautmann, G.H.	797	Uematsu, R.	588	Vassilopoulos, L.	1642
Traveaux, P.J.	2649	Uematsu, S.	2371	Vasudevan, R.	889
Travi, S.	1823	Ueyama, H.	1832	Vatterott, K.H.	1241
Trayner, B.T.	2576	Uffer, R.	1706	Vaughan, D.K.	1359
Tree, D.R.	1089, 2227	Uicker, J.J., Jr.	1554, 1555	Vaughan, V.L., Jr.	751, 930
Trent, B.C.	2540	Ujihashi, S.	359, 1680	Vdoviak, J.W.	1859
Trifunac, M.D.	2195	Ukeje, E.	1978	Velinsky, S.A.	902
Trivett, D.H.	1700	Ulbrich, H.	2572	Veluswami, M.A.	120, 121
Trn, R.M.	415	Umesato, K.	1917	Veneziana, D.	2561
Troeder, C.	1240, 1650, 2525	Underwood, P.	1982	Venkatesan, C.	1461
Troeder, Ch.	1815	Underwood, P.G.	712	Venkayya, V.B.	929, 1454
Trommer, W.	1996	Unruh, J.F.	2555	Vepa, R.	2
Trubert, M.R.	48	Unz, H.	1034, 1294	Verchery, G.	2028
Trunzo, R.	2051	Urbanczyk, M.	1977	Verheest, F.	2450
Truong, K.T.	1287	Urbanik, T.J.	2076	Verma, J.P.	2384
Tsai, M.S.	380	Ushijima, Y.	2323	Vermeulen, P.J.	634
Tseng, K.	714	Usui, T.	1496	Vernière De Iassar, P.L.	1905
Tsirk, A.	1198	Utku, S.	2124	Vestroni, F.	.820, 963
Tsubokura, K.	327, 2367			Větrovec, K.	.21
Tsuda, Y.	955			Viano, D.C.	2091, 2327
Tsui, C.C.	158			Victor, F.	2518
Tsui, M.	2130, 2131			Viegas Gago, A.F.	982
Tsui, Y.T.	158			Vijay, D.K.	367
Tsukikawa, T.	1832			Villaverde, R.	.16
Tsurui, A.	2643			Vincent, J.H.	2559
Tsushima, N.	1645			Vincent, R.Q.	2412
Tuccio, M.	1151	Vaicaitis, R.	98	Virchis, V.J.	1588
Turcic, D.A.	1489, 2378	Valentin, R.A.	.801, 803	Visscher, W.M.	1304
Turczyn, M.T.	571	Valid, R.	1056, 2019	Viswanathan, S.P.	553
Turhan, D.	167	van Baten, T.J.	978	Viti, G.	1823
Turkel, E.	1966	Van Benschoten, J.	1104	Vlach, J.	1771
Turnbow, J.W.	1223	Van Buren, A.L.	1534, 1700	Voelsen, P.	1847
Turner, C.D.	2345	Vance, J.M.	.503, 725, 1579, 2592	Vogel, W.	1676
Turner, J.D.	295	Van Dao, N.	.647, 1763	Vogt, G.	2373
Turula, P.	1678	VandenBrulle, P.J.	304	Vogt, L.	570
Tustin, W.	1357	Vanderhart, D.L.	2012	Volcy, G.C.	.37, 928
Tuten, J.M.	274	van der Kooij, J.	2333	Volkert, O.	1637
Tuttle, M.	2519	Vanderpool, M.E.	1681	Vömel, M.	1997
Tylkowski, A.	868	Vandiver, J.K.	.85, 1428	von Buseck, C.R.	.910
Tzeng, S.-T.K.	1299	Van Gemert, D.A.	2536	von Reyn, T.	2230
Tzuang, S.	827	Van Haren, J.	322	Von Riesemann, W.A.	.28
		Van Honacker, P.	.322, 1607	Voorhees, C.	2089
		van Nunen, J.W.G.	.881	Voorhees, C.R.	.150
		van Willigenburg, J.J.	.1206	Voros, G.	2454
		Varadan, T.K.	.1492	Vosikovsky, O.	2642
		Varadan, V.K.	.1699	Voyiadjis, G.Z.	.1927
		Varadan, V.V.	.1699	Vulfson, J.I.	.1655
		Varga, T.	.1992	Vullo, V.	.6, 7

## U

Überall, H.	148
Udwadia, F.E.	2678

## W

Waas, Ph.D.G.	1830	Wasner, O.	232	White, K.R.	1099
Waberski, A.	615, 2489	Wasserman, D.E.	861	White, M.R.	560
Wachel, J.C.	521, 1686	Watanabe, J.	1832	White, R.	1667
Wachter, J.	606, 2593	Watanabe, K.	2312, 2397, 2471	White, R.A.	902
Wada, H.	2298	Watanabe, N.	2122	White, R.G.	995, 2096, 2150
Wagner, P.	1281, 1950	Watanabe, T.	1495	White, R.N.	27
Wagner, R.	689	Watanabe, Y.	2552	Whitehead, D.S.	1478
Wahi, K.K.	2540	Waters, D.M.	1877	Whitehead, D.W.	1477
Waine, B.R.	1201	Waters, P.E.	1165	Whitesell, J.E.	1778
Waldon, C.A.	1993	Watkins, J.C.	717	Whitford, L.	2100
Walford, T.L.H.	1239, 2571	Watson, H.E.	265	Whitney, A.K.	1953, 1954
Walgrave, S.C.	548	Watson, L.T.	2173	Whitney, M.G.	646
Walker, A.W.	1311, 2004	Watt, B.J.	1838	Whitt, J.B.	2244
Walker, K.C.	900, 901	Watt, W.	205	Whittaker, A.R.	880
Walker, R.	1880	Watters, R.B.	956	Whitton, P.N.	1335
Walker, R.E.	639	Wauer, J.	1829	Wicher, J.	1235
Walker, S.	894	Waugh, C.B.	28	Wierzbicki, T.	357, 1762
Wall, D.J.N.	1699	Wearing, J.L.	2588	Wieser, P.	326
Wallace, M.M.	625	Weaver, D.S.	2169, 2170	Wilby, E.G.	936, 1213
Wallace, R.I.	233	Weaver, H.J.	888	Wilby, J.F.	936, 1213
Wallace, T.F.	47	Weaver, R.L.	2181	Wildheim, J.	2203
Waller, H.	429, 430	Weber, K.	1573	Wilding, R.	2089
Walpert, H.	2198	Weck, M.	2376	Wilkinson, C.D.W.	1514
Walsh, M.J.	1632	Wedig, W.	464, 971, 2018, 2679	Wilkinson, D.H.	82
Walter, C.E.	233	Weglein, A.B.	1300, 1301	Wilkinson, R.H.	2389
Walter, J.L.	781	Wegner, J.G.	1882	Willey, E.	787
Walton, W.	1835	Wehage, R.	2680	Williams, R.	1986
Walton, W.S.	636	Weimer, F.C.	2273	Williams, R.J.	2492
Wambsganss, M.W.	1019	Weiming, T.	240, 386	Williams, R.S.	449
Wan, F.Y.M.	310	Weiner, E.O.	259	Willis, J.R.	1045, 1046, 1302
Wandrisco, J.M.	64	Weingarten, V.I.	2619	Wilshire, W.L., Jr.	1610
Wang, A.J.	2361	Weinstock, H.	920, 2553	Wilson, D.	1744
Wang, B.P.	2269	Weiss, R.A.	1107	Wilson, E.L.	1426, 1590
Wang, C.C.	2300, 2494	Weissmann, G.F.	2440	Wilson, J.C.	731
Wang, K.L.	2113, 2114	Wells, W.R.	1221	Wilson, J.F.	2385
Wang, P.C.	30	Wenger, W.A.B.	2178	Wilson, R.B.	2374
Wang, S.J.	1592	Wenlong, L.	2462	Wiltzsch, M.	331
Wang, T.-M.	1662	Wernicke, G.	1730	Winkler, C.	2684, 2685
Wang, X.	1238	Wesley, D.A.	893	Winkler, C.B.	61, 182
Wang, Y.F.	364	West, B.	1618	Winter, R.	46, 2190
Wang, Y.-g.	2424	West, H.H.	83	Winterstätter, A.	2458
Wanhill, R.J.H.	953	Westermo, B.D.	2123	Witmer, E.A.	663, 2125
Warburton, G.B.	1881	Westervelt, P.J.	2185	Witte, G.	1532
Ware, P.M.	2579	Westine, P.S.	643	Wittlin, G.	1572
Warren, R.E.	1414	Wevers, L.J.	1576	Wittman, L.J.	497
Warring, R.H.	943	Wey, J.	5	Witwer, K.Z.	1746
Washizu, K.	1253	Whaley, P.W.	112	Włodarczyk, E.	2186, 2191
		Wharf, J.H.	568	Wojewódzki, W.	2408
		Whiston, G.S.	89	Wojno, W.	357
		White, B.A.	197	Wolf, C.	232
		White, E.R.	1370	Wolf, J.A., Jr.	2470

Wolf, J.P.	242, 251, 400	Yamamoto, S.	29, 1832	Young, B.	1147
Wölfel, J.	162	Yamamoto, T.	1403, 1407	Young, C.	2540
Wolff, F.H.	484, 608, 2118, 2268	Yamane, T.	2344	Young, J.A.	891, 2331
Woltornist, W.	2080	Yamazaki, Y.	1705	Young, J.Y.	1908
Wood, W.L.	1560	Yan, L.-T.	2049	Young, M.I.	1412
Woodhouse, J.	2499	Yanabe, S.	1575, 2522	Youngdahl, C.K.	801, 803
Woodsum, H.C.	2185	Yang, C.S.	2250	Yu, B.-K.	1254, 1953
Woodward, K.A.	2133	Yang, C.Y.	1423, 1424, 2066	Yu, I.-W.	418
Woodward, R.P.	1413	Yang, D.	441	Yu, Y.H.	1225, 1586
Woollett, R.S.	671	Yang, G.P.	1238	Yuceoglu, U.	824
Woomer, E.	1543	Yang, H.H.	1238	Yun, C.B.	30
Wormley, D.N.	1427, 1434, 1811	Yang, J.C.S.	2198	Yuruzume, I.	325, 2369
Worthington, P.J.	1342	Yang, J.N.	1822	Yuzawa, M.	1973
Wright, J.P.	1594	Yao, J.T.P.	2062	Z	
Wright, R.N.	2691	Yang, T.Y.	890	Zaghlool, S.A.	1101
Wróblewski, J.E.	1787, 1788, ....., 1793, 1794	Yang, W.H.	1086	Zak, A.R.	1269
Wu, J.H.T.	1519, 1981	Yaniv, S.L.	150	Zak, K.	121
Wu, J.J.	2127, 2128	Yano, S.	219	Zandt, G.	254
Wu, J.-T.	1897	Yanome, M.	2364	Zedan, M.F.	1908
Wu, S.M.	2059, 2306, 2476	Yao, J.T.P.	1777	Zeid, I.	8
Wu, S.T.	239	Yates, D.G.	688	Zeng, C.-h.	1870
Wu, W.	1312	Yates, J.E.	1509	Zettlemoyer, N.	238, 1189
Wu, Y.-s.	1870	Yau, W.F.	1518	Zhongquan, X.	248
Wulff, W.	1146	Yazaki, K.	2318	Zhongmin, Y.	2462
Wyskida, R.M.	574, 1474	Yeager, D.M.	387	Zhou, Z.-w.	2424
Wyssmann, H.R.	516	Yeager, W.T., Jr.	1585	Zhuravlev, V.F.	2568
X		Yee, G.	1359	Ziaran, S.	1242
Xianquan, D.	2462	Yeh, H.H.	2034	Zielke, W.	1598
Xistris, G.D.	191	Yen, B.T.	1186, 1187	Zimmerman, H.	1133
Y		Yen, C.-L.	1017, 2410, 2611	Zimmerman, R.M.	1099
Yaghmai, I.	2115	Yen, D.H.Y.	774	Zimmermann, T.	2168
Yam, K.	1234	Yerges, J.F.	631	Zinn, B.	1611
Yamada, G.	92, 337, 358, 768, ....., 1261, 1262, 1917, 2143	Yeung, K.S.	1127	Zinn, B.T.	1505
Yamada, M.	1407	Yim, C.	773	Zirin, L.	1580
Yamada, T.	1717	Yin, S.K.	35	Zlokolica, M.Z.	1557
Yamagishi, K.	2344	Ying, S.P.	394, 526	Zogg, H.	228
Yamaguchi, T.	1268	Yoda, K.	2393	Zorumski, W.E.	1864
Yamaki, N.	965, 966, 2398	Yokoi, M.	1307	Zorzi, E.	2662
		Yokoya, Y.	2434	Zorzi, E.S.	831
		Yokoyama, Y.	2061	Zubavičius, L.	595
		Yoneda, R.	2417	Zwicke, P.E.	284
		Yonkovich, G.	301	Zvolanek, I.	2516
		Yoneya, T.	1840		
		Yoo, C.H.	1910		
		Yoshida, H.	1955		
		Yoshida, K.	1840		
		Yoshimura, T.	2471		
		Younes, Y.K.	1480		

## ANNUAL SUBJECT INDEX

<b>A</b>	Acoustic Excitation					
	390	41	1034	105	1017	1018
	2150	781	2254	285	1667	1218
			2410	2141	345	2147
					1465	1628
Absorbers (Equipment)					2315	
1680	1881	1023	954			
Absorbers (Materials)						
810		2183	146			
Acceleration Analysis						
681	682	1953	636			
Acceleration Effects						
2050			2506			
Acceleration Measurement						
902				2229		
Accelerometers						
		435	446			
		665	1746			
Acoustic Absorbers						
		55				
Acoustic Absorption						
170	141	942	613	1514	145	146
380		1882	943	1884	1955	1966
480			2183	2624	2005	
810						
1880						
Acoustic Arrays						
2430			1534	2625		
Acoustic Attenuation						
use Acoustic Absorption						
Acoustic Detection						
1501			2475			
Acoustic Emission						
440	1111	142	1363	444	1545	1736
1110	1371	442	2403	1544	2016	447
1750	1751	1342			1348	1109
2060		2404			2448	1599
		1832			2469	
		2402				
Abstract						
Numbers:	1-217	218-483	484-719	720-886	887-1167	1168-1402
						1403-1574
						1575-1799
						1800-2046
						2047-2289
						2280-2504
						2505-2691
Volume 13						
Issue:	1	2	3	4	5	6
	7	8	9	10	11	12

<b>Acoustic Resonators</b>	<b>1174</b>		<b>Aerodynamic Characteristics</b>			
			1351 1102 1453		476	417
			1221 1442			1709
<b>Acoustic Response</b>				<b>Aerodynamic Damping</b>		
391 842 1293	2465	1918				759
1031 2142 1513						2009
<b>Acoustic Scattering</b>				<b>Aerodynamic Excitation</b>		
140 151 1702	2185	139			287	1429
		349				
		2429				
<b>Acoustic Signatures</b>				<b>Aerodynamic Loads</b>		
1970 1541				1220 1791 1752	714	66 937 1388 1159
				1620 1792	1624	1226 1057 1389
				1790		2117 2009
<b>Acoustic Spectra</b>				<b>Aerodynamic Noise</b>		
1690					754	1487
<b>Acoustic Tests</b>				<b>Aerodynamic Response</b>		
1811 1832	995			use Aerodynamic Stability		
2011						
<b>Acoustic Waves</b>				<b>Aerodynamic Stability</b>		
2390 1562		387 1508				1567
<b>Acoustical Data</b>				<b>Aeroelasticity</b>		
Use Experimental Data				872 1463 1764		
				1652		
<b>Active Control</b>				<b>Agricultural Machinery</b>		
2211	284 1975	1627 498			744 745	537 578
		1258				577
<b>Active Damping</b>				<b>Air Bags (Safety Restraint Systems)</b>		
420 2211	2565	657	1989			2327
830			2209			
<b>Active Flutter Control</b>				<b>Air Blast</b>		
1460 1452		1457 1458 1459				1317
1622		2357 1868 1619		<b>Airborne Equipment Response</b>		
				681 112		556 287
				682		
<b>Active Noise Control</b>				<b>Air Compressors</b>		
	2174			use Compressors		
<b>Active Vibration Control</b>				<b>Air Conditioning Equipment</b>		
2210						1196
<b>Actuators</b>						1976
		1299				
<b>Aerial Explosions</b>				<b>Aircraft</b>		
1521				210 41 42 43 44 285 936 47 118 289		
				290 1221 752 1213 714 1015 1016 937 228 1159		
				(cont'd)		

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2290-2604 2605-2891

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Aircraft (continued)		Airframes	
1220 1371 1332 1623 1224 1445 1866 947 668 1219			936 1217
1440 1461 1442 1793 1794 1455 2086 1137 1218 1459			
1460 1621 1452 2343 2345 2556 1457 1348 1619			
1870 1751 1462 1871 1622 1537 1458 1869			
1991 2082 1617 1568			
2237 2558 1867 1618			
2357 2357			
Aircraft Carriers	704	Airports	
		441 632 2063 1464	2087
		2622 2544	
Aircraft Engines		Algorithms	
1370 1033 1745 1547 1369		202 1133 424	
1293 1727 2029			
2117 2049			
2557			
Aircraft Equipment	1147	Aligning	
		use Alignment	
		Alignment	
510 511 512 513 334		596	588
1643 514			708
2573 1694			
Aircraft Equipment Response	2236	Aluminum	
		2343 2354 835	
		995	
		1525	
Aircraft Noise		Ammunition	
40 51 282 283 934 935 1216 817 1148 49		812 1883	645
680 381 932 753 1214 1155 1446 1447 1858 1629			
1390 1211 1032 933 1444 1215 1616 1857 2338 1859			
1610 1631 1212 1443 1614 1615 2047 2339			
1630 1861 1392 1613 1864 1865 2337			
1860 2341 1612 1863 2084 2085			
1862 2083 2234 2555			
2342			
2622			
Aircraft Seat Belts		Amplifiers	
1222		1075	
Aircraft Seats		Amplification	
1222		1865 1966	
Aircraft Vibration	1213	Amplitude Analysis	
		2230 2524 1836 1658	
Aircraft Wings		Amplitude Data	
680 1752 1453 1454 1085 286 1217 1868 929			2278
1620 2035 1456 1567			
Airfoils		Amplitude Measurement	
1441 2103 1624	1968 1509	174	
	1709		
		Amplitude Modulation	
		1334	
		Analog Simulation	
		450 532	
		Anechoic Chambers	
		2014	

Abstract

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Angular Vibration</b>				<b>Artillery Fire</b>		
2300				812		
	667	648				
		668				
<b>Animal Response</b>				<b>Asymmetry</b>		
571				2600	1173	
					2513	
<b>Anisotropic Properties</b>				<b>Asymptotic Approximation</b>		
<i>use Anisotropy</i>					1965	
<b>Anisotropy</b>				<b>Asymptotic Series</b>		
	2506			360		409
<b>Annular Disks</b>				<b>Asynchronous Motors</b>		
111 1002					1814	
	2148	99		<b>Automated Testing</b>		
<b>Annular Plates</b>				691	694	
100 1001 352 353	2396	358		1361		438
1260 1261 2603		2398				
<b>Antennae</b>				<b>Automated Transportation Systems</b>		
2080 1592 433			1909		276	
<b>Antiecomorphic Diamines</b>				<b>Automatic Control</b>		
					1183	
<b>Antifriction Bearings</b>				<b>Automobile Bodies</b>		
<i>use Rolling Contact Bearings</i>					2375	
<b>Antiphase Technique</b>				<b>Automobile Noise</b>		
	2174			2320 2321		2318 2319
<b>Approximate Methods</b>				2470		
<i>use Approximation Methods</i>				<b>Automobile Seat Belts</b>		
<b>Approximation Methods</b>				1632		277
1752	2256	1007 988		<b>Automobile Tires</b>		
		1067				1887
<b>Arches</b>				<b>Automobiles</b>		
	976	2137 348		2551 742 913 904 905 906		
<b>Armored Vehicles</b>				2651 2322 1843	915	
	636			<b>Axial Excitation</b>		
				91 1913		
<b>Arrays</b>					467 338 2449	
	1534				2358	
<b>Articulated Vehicles</b>				<b>Axial Force</b>		
742 33 2684 1605 2686 2077					1492	
743	1845			<b>Axial Vibration</b>		
	2685			1042		1246
				1082		339
				1942		

---

**Abstract**

Numbers: 1-217 218-483 484-719 720-888 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**


---

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

---

Axissymmetric Bodies		
1711		638
Axissymmetric Vibrations		
2400	1945	
Axle Acceleration		
902		

Beams (continued)		
970 1041 1662 1663 2154 1875		967 1888 1249
1040 1661 1762 1783 2204 1905		1247 2128 1659
1140 1691 1902 1903 2214 2125		1337 2598 1829
1250 1901 2122 2123 2384 2385		1907 1899
1660 2511 2382 2383		2127 2129
1900		2387 2589
2270		2599
2600		

Beams - Columns  
2115

- B -

Baffles		
2151	2563 944	
Balancing		
use Balancing Techniques		
Balancing Techniques		
700 701 702 703 2474 445 596 697 2668 2669		
1741 1742 1543 2664 1115 1116 1367 2688		
2661 2252 1743	1365 1336 2667	
2532 2253	2665 2666	
2662 2663		
Ball Bearings		
185	2568 319	2580
955	1239	2660
1645	2659	2670
2105		
Barges		
1841		
Bars		
2644 2445 1246 337 338 339		
638		
Base Excitation		
2292 2123	2095	2387 2098 2097
2199		
2409		
Beams		
90 91 92 93 184 625 966 87 88 89		
340 341 342 313 964 965 1906 267 968 469		
450 451 572 343 1324 1475 2126 667 1248 539		
610 611 1082 473 1904 1495 2386 767 1338 609		
710 971 1492 1493 1954 1765	867 1588 969	
(cont'd)		

Abstract  
Numbers: 1-217 218-483 484-719 720-806 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2891

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Bibliographies</b>		<b>Boilers</b>		
1400 481 482 483 1794 1795 1166 1167 1788 1789		1353 134	2136	129
1790 1401 1402 1793	1796 1787 1798			
1791 1792	1797			
<b>Bifurcation Theory</b>		<b>Boiling Water Reactors</b>		
1761		81 23		
<b>Bird Strikes</b>		<b>Bolotin Method</b>		978
	1618			
<b>Bispectral Analysis</b>		<b>Bolts</b>		
1112		1991 1653		958
<b>Blade Loss Dynamics</b>		<b>Bonded Structures</b>		
222		2343		2589
2292		<b>Bond Graphs</b>		
		use Bond Graph Technique		
<b>Blades</b>		<b>Bond Graph Technique</b>		
310 311 212 313 224 865 66 67 948 579		1380 841 462	1755	177
950 951 312 873 314	2566 1477 1478 1229			1587
1640 1931 952 953 524	1727 1888 1889			
1720 2041 2102 2103 954	2037 2038 2039			
2040 2101 2362 2363 1744	2239			
2100 2361	2364			
2360 2511		<b>Bones</b>		
		2091		
<b>Blast Effects</b>		<b>Booster Rockets</b>		
	643	561 562		
<b>Blast Excitation</b>		<b>Boundary Condition Effects</b>		
640 641 642 853		1940 1011 124 1925 1326 867 2608		
2311		1924		
<b>Blast Loads</b>		<b>Boundary Element Technique</b>		
	2008	1982		
<b>Blast Resistant Construction</b>		<b>Boundary Layer Damping</b>		
use Blast Resistant Structures		1323		
<b>Blast Resistant Design</b>		<b>Boundary Layer Excitation</b>		
use Blast Resistant Structures			2606	
<b>Blast Response</b>		<b>Boundary Value Problems</b>		
	619	1762 113 1254 2025	397	709
	2629	2023		2489
<b>Blowdown Response</b>		<b>Box Beams</b>		
2172			236	
<b>Blowers</b>		<b>Box Girders</b>		
	1174		1185 1186 1187	1189
	1784			
		<b>Box Type Structures</b>		
			246	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2604 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Braces</b>					<b>Calibrating</b>			
240		1194		2178		1702	2234	1726
<b>Braking Effects</b>					<b>Calibration</b>			
1462		2684	2685	1476	use Calibrating			
				2686				
<b>Branched Systems</b>					<b>Cam Followers</b>			
391		1024		2676				2378 1489
		2054			<b>Cams</b>			1489
<b>Bridges</b>					<b>Camshafts</b>			
1190 11 12 253		1185	236	237	238	729		
1820 881		2075	256	1167	728	1099		1489
2310 1191			1166	1187	1188	1189		
			1186		1588	2309		
					1938			
					2438			
					<b>Cantilever Beams</b>			
					90 2391	363 184		967 1888 769
					1210	1663 2124		1907 1908
					1680			2387
<b>Buildings</b>					<b>Cantilever Plates</b>			
240 241 242 13 14 15 16 17 18 239		1000	112		114 855			
830 731 882 243 244 245 246 267 658 1399					2294			
1420 1591 1192 533 1194 1255 1166 1167 1398 1589								
1590 1821 1822 613 2064 1195 1196 2537 2189								
1921 2062 633 2194 2535 2536								
2311 883								
2561 1004								
2691 1193								
1823								
2063								
<b>Bumpers</b>					<b>Cascades</b>			
		1637			2101			1477 1889
<b>Buses</b>								2567
			1207		<b>Catenaries</b>			597
<b>Cables (Ropes)</b>					<b>Cavitation</b>			
2380 1491 962 83 84 85 766 607 608 2119		471		1114				1049
963 1364 765 1657 1898					<b>Cavitation Noise</b>			
1245 2388					1445			
<b>Cable-Stiffened Structures</b>					<b>Cavities</b>			
881		1909			2443 2444 2065			
971								
1191					<b>Cavity-Containing Media</b>			
1421					2065			1699
<b>Cables (Ropes)</b>					<b>Cavity Resonators</b>			
2380 1491 962 83 84 85 766 607 608 2119					2321			
963 1364 765 1657 1898								
1245 2388					<b>Celestial Bodies</b>			
					2436			

**Abstract**

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2280-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Cell-to-Cell Mapping</b>		<b>Collapse</b>	
2262 2263		use Failure Analysis	
<b>Centrifugal Pumps</b>		<b>Collision Research (Aircraft)</b>	
2533	228 519	use Crash Research (Aircraft)	
<b>Cepstrum Analysis</b>		<b>Collision Research (Automotive)</b>	
1364	1088	900 551 1632 693 904 155 906 277 1468 689 2190 901 2502 1313 1314 905 1606 1127 2078 899 2330 1373 2354 1605 2326 2327 2328 2329 2503 2554 2355 2488	
<b>Ceramics</b>	1339		
<b>Chain Drives</b>	1817	<b>Collision Research (Railroad)</b>	
		715	548 549
<b>Chatter</b>		<b>Collision Research (Ships)</b>	
880 231 232 531 1182	2574 2307 2059	1373 2336	
<b>Chimneys</b>		<b>Columns</b>	
971 972		251 772 773 975 2536 97 1665 347	1059
<b>Circular Cylinders</b>		<b>Columns (Supports)</b>	
1911	1494	2391 2133	
<b>Circular Membranes</b>		<b>Combination Resonance</b>	
1930			1059
<b>Circular Plates</b>		<b>Combustion Engines</b>	
100 101 102 1003 1934 1935 1930 1671 1932 1933 2144 2145 2400 2332 2395	2147 358 779 2157 1268 1259		2587
<b>Circular Saws</b>		<b>Combustion Noise</b>	
2362	1258 1479	2323 2085	
<b>Circular Shells</b>		<b>Compacting</b>	
360 1681 2612	124 2164		2544
<b>Clay Soils</b>	2466	<b>Complete Quadratic Combination Method</b>	
		1590	
<b>Clearance Effects</b>		<b>Complex Structures</b>	
1240 1802	1495	2483	
1650	1895	<b>Component Mode Analysis</b>	
		1381	
<b>Coherence Function Technique</b>		<b>Component Mode Synthesis</b>	
394		2590 2292	1608 2239
<b>Collocation Method</b>	2028	<b>Composite Materials</b>	
		210 1041 152 660 1741 412 680 2181 612 1440 1302 1342	414 625 426 837 1628 1454 776 1046

---

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2681

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

---

<b>Composite Structures</b>		<b>Concentric Structures</b>	
1000 481	2166 1937	998 1039	1677
1041		1038 1929	
1991		2149	
2031		2439	
<b>Composites</b>	<b>944</b>		
<b>Compressor Blades</b>			
2100	1744 855	67 948 579	
<b>Compressors</b>			
521 522 523 604	495 496 497	518 1739	
2301 2532 2593 1174	515 516 727	2009	
	725 536		
	2665		
<b>Computer-Aided Techniques</b>			
80 691 172 163 1714	205 676 877	1208 509	
1370 931 812 473 1794	706	1558 959	
2000 1742 1713 2664	1546	2248 1369	
2010 2322 1793	2356	2668 1579	
2680 2492 1843	2596	1749	
2652 1873		2299	
2073		2319	
2253			
2663			
<b>Computer Programs</b>			
420 291 22 293 74 5 46	7 18 269		
470 311 232 633 204 205 206	207 218 469		
540 471 292 653 474 405	466 367 268 1069		
890 801 402 713 364 475	476 417 418 1149		
1150 1151 472 773 714 715	736 467 428 1359		
1390 1201 712 813 854 855	856 477 468 1389		
1980 1391 722 853 874 1155	1006 607 478 1559		
2120 1521 862 1153 1154 1255	1056 717 858 1779		
2510 1611 892 1193 1224 1455	1146 857 918 1789		
1711 1152 1393 1454 1465 1466	897 1108 1889		
1891 1392 1453 2044 1565 1566	1127 1148 2039		
2041 1522 2043 2064 2035	1786 1147 1228 2069		
2321 2042 1913 2094 2045	2036 1387 1388 2159		
2282 2283 2124 2125	2166 1477 1578		
2342 2503 2284 2275	2286 1567 1618		
2502 2683 2504 2285	2686 1657 1678		
2682 2684 2685	1687 2038		
	2037 2068		
	2167		
	2177		
	2687		
<b>Computerized Simulation</b>			
1632	864		

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1790 1800-2046 2047-2289 2290-2504 2605-2891

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

---

**Abstract**

**Numbers:** 1-217 218-483 484-719 720-866 867-1187 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2280-2504 2505-2891

Volume 13

**Issue:**      **1**      **2**      **3**      **4**      **5**      **6**      **7**      **8**      **9**      **10**      **11**      **12**

<b>Crash Research (Aircraft)</b>		<b>Cylinders</b>	
930 751 402 1223 474 45 46	2168	770 771 612 973 974 95 96	878 2179
2190 1222 1373	2558	1010 1911 1252 1253 1254 855 346	2388 2389
1572 1873		1050 2131 2132 2123 1494 1715 1836	2629
1872		1100 2161 2413 1664 2415	
<b>Crashworthiness</b>		<b>Cylindrical Beams</b>	
2190 1222 1223	715 2326 47 548 549		1337 1338
	2558		
<b>Critical Damping</b>		<b>Cylindrical Bodies</b>	
1901 1082 423	2208	use Cylinders	
<b>Critical Excitation Method</b>		<b>Cylindrical Shells</b>	
	1198	120 121 782 403 124 1015 426 1017 118 119	
<b>Critical Response Spectra</b>	154	360 771 1012 783 1014 1275 1016 1677 368 359	
		1010 781 1282 973 1944 1405 1276 2407 1498 1679	
<b>Critical Speeds</b>		1280 1011 1682 1013 2164 1715 1676 1678 2409	
870 722 2053	475	1680 1681 1762 1673 2105 2406 2608 2609	
1170 2512	1575	1940 1941 1942 1943 2165	
2050 2522		2180 2161 2162 2163	
<b>Cross Correlation Technique</b>		2390 2611 2612	
463	1446	2410	
2003		2610	
<hr/>		<hr/>	<hr/>
<b>Cross Spectral Method</b>		<b>- D -</b>	
2233			
<b>Curved Beams</b>		<b>Damage Prediction</b>	
1910 1662 1783	2386 87 768 609	243 254 735	
	337	2225	
<b>Curved Ducts</b>		<b>Damped Modes</b>	
1961			1756
<b>Curved Plates</b>		<b>Damped Structures</b>	
1041	1257	1070 2391 2022 1923 2144	1376 407 1078
		2023	
<b>Cushioning</b>		<b>Damped Systems</b>	
use Impact Shock Insulation		1760 2143	2208
			2218
<b>Cushioning Materials</b>		<b>Damper Locations</b>	
use Packaging Materials			875
<b>Cutting</b>		<b>Dampers</b>	
1182		1080 421 2213 214 875 2116	419
<b>Cyclic Loading</b>		2633 2214 2565	1999
440 592 2133	2176 2178 599	2634	
2222			

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2604 2605-2891

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Damping</b>		<b>Design Techniques (continued)</b>
580 1041 2212 213 1584 1805 1076	2058 1079	530 1411 1142 1473 854 1145 2356 877 1778 789
1200 1081 2532	2126	750 2281 1892 1893 1104 1565 2646 2427 1958 959
		1510 1992 2013 1244 2425 2358 1199
		2680 2093 1564 2558 1579
<b>Damping Characteristics</b>		1674 1789
1340	384 2585	2218
		2394
<b>Damping Coefficients</b>		<b>Detectors</b>
590 1651 422 223 725 316	308 1129	1530 1872 2078
1660 1911 542 603 1725 586	518 1339	
2110 2291 1582 653 654 1885 656	558 1809	<b>Diagnostic Instrumentation</b>
2230 2571 1642 1193 2105 2376	1758	1110
2550 2582 1653 2215 2466	1828	<b>Diagnostic Techniques</b>
		1110 1111 442 443 444 185 696 677 698 699
2632 2583		1360 1361 1112 1113 1114 705 716 697 718 1109
<b>Damping Effects</b>		2470 1501 1362 1363 1364 2475 2016 2017 1108 1369
1560 502 1903 294 605 826 377 348 219		1541 1542 1574 2655 2656 2657 1738 1739
2050 2522 424 825 1556 2677	499	2251 2468 2469
2170 2612 584	2049	2471 2658 2679
2440	724	
<b>Damping Materials</b>		<b>Diaphragm Couplings</b>
2362	1704	596 1187
<b>Damping Values</b>		<b>Diesel Engines</b>
use Damping Coefficients		720 1542 324 2325 527 878 229
		2252 2552
<b>Dams</b>		<b>Difference Equations</b>
1831 1422 253 1424 1595 1166 1167	479	1379
2541 2202 1363	1596 1597	
2542 1423	2066 2067	
2543	2317	
<b>Data Presentation</b>		<b>Differential Equations</b>
150 2362	178	2482 2264 1378
<b>Data Processing</b>		<b>Digital Filters</b>
1372 704 576	188 2319	2460 1731 2002 1123 1535 429
1892	2488	
2062		<b>Digital Simulation</b>
		33
<b>Data Reduction</b>		<b>Digital Techniques</b>
use Data Processing		1532 2073 1734 1106 168
		2372
<b>Decay Laws</b>		<b>Dimensional Analysis</b>
	1309	1565
<b>Describing Function Approach</b>		<b>Dimensional Measurement</b>
	2486	1799
<b>Design Techniques</b>		<b>Direct Computational Method</b>
80 591 62 3 164 315 6 7 448 209		451
210 1181 72 473 314 1075 2216 787 628 749	(cont'd)	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1709 1800-2046 2047-2289 2290-2604 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Direct Fourier Synthesis</b>		<b>Drive Line Vibrations</b>	
	<b>2026</b>		<b>527</b>
<b>Discontinuity-Containing Media</b>		<b>Drive Shafts</b>	
2620 1321 2162	1014 1045 1046 1667	1802	2525
	2445	1968	2609
<b>Discs</b>		<b>Drop Tests</b>	
use Discs			574
<b>Disk Springs</b>		<b>Ducts</b>	
	56	170 381 382 383 624 135 136 1037 1288 1959	
		380 1291 1032 573 1034 565 1036 1957 1958	
		610 1471 1292 1033 1234 1035 1506	
		1290 1961 2422 1293 1294 1295 1956	
		1690 2421 1853 2174 1505	
		1960 2173 1955	
		2420 2423 2175	
		2620 2563	
<b>Disks</b>		<b>Duffing's Differential Equation</b>	
use Discs (Shapes)		1770	
<b>Disks (Shapes)</b>		<b>Dynamic Absorbers</b>	
2040 1091 1002 2143 224	1936	2093	
2112 2363 994	1258		
2362	1178		
2512	2148		
<b>Displacement Analysis</b>		<b>Dynamic Balancing</b>	
1953	2019	703	
<b>Displacement Measurement</b>		<b>Dynamic Buckling</b>	
1092 434 105	668	120 121 122 123 664 1665 366 97 88	
435		361 1692 784 796 347 2408	
		2121	
<b>Displacement Transducers</b>		<b>Dynamic Data System Technique</b>	
433	1996	851	2306
			2476
<b>Domes</b>			2059
1005 1006	1008		
<b>Doppler Effects</b>		<b>Dynamic Excitation</b>	
	189	use Dynamic Response	
<b>Double Summation Procedure</b>			
1283			
<b>Doubly Asymptotic Approximation Method</b>		<b>Dynamic Loads</b>	
1982 2254		use Dynamic Response	
<b>Drilling Platforms</b>		<b>Dynamic Modulus of Elasticity</b>	
2550	1837 1838 1839	1071	
	2317		
<b>Drills</b>		<b>Dynamic Plasticity</b>	
2381	2476 627	1040	1934
	1419		88
	1819		
<b>Drillships</b>		<b>Dynamic Programming</b>	
use Drills and Ships		1773 1774	
<b>Abstract</b>		<b>Dynamic Properties</b>	
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691		746	
<b>Volume 13</b>			
<b>Issue:</b>	1 2 3 4 5 6 7 8 9 10 11 12		

**Dynamic Relaxation**  
1201

- E -

**Dynamic Response**

1440 821 2272 743 2114 195 346 367 318 79  
1151 2113 1897 1208 229  
2099

**Ears**

1267

**Dynamic Shear Modulus**

2466

**Earthquake Damage**

371 1192 243 254 795 2066 2627 1198  
1591 1423 1424  
2541

**Dynamic Stability**

1761 1412

1394 585 656

498

**Earthquake Prediction**

1318

**Dynamic Stiffness**

70 1041 732  
1901

**Earthquake Resistant Design**  
use Earthquake Resistant Structures

**Dynamic Stress Concentration**

2024

1699

**Earthquake Resistant Structures**

2601 1673 2195 1777 738  
2691

**Dynamic Structural Analysis**

1060 81 712 843 1224 825 166 1057 18 199  
431 1754 1135 336 198 709  
2401 2264 766 1558

**Earthquake Response**

180 731 242 153 244 1255 1596 1277 1838  
260 1921 1712 1503 1594 1705 2176 2537  
820 2561 1962 1673 2044  
860 2392 1963  
2540 2543

**Dynamic Structural Response**  
use Dynamic Response

**Dynamic Synthesis**

1654

**Earthquake Simulation**

2542 1194 637  
2674

**Dynamic Systems**

1561 2262 2263  
2261

466

1768

**Earthquakes**

891 1072 823 2194 1826 797 1319  
1831 2309

**Dynamic Tests**

180 31 2542 233 24 25 1536 1197 598 309  
540 181 543 694 685 1667 888 559  
930 541 603 1314 1605 1539  
1580 1251 1313 1854  
2653

**Eigenvalue Problems**

710 221 842 193 924 2025 196 457 1118 1119  
870 1941 1522 2683 1754 2495 456 2477 2478  
2022

**Dynamic Vibration Absorption (Equipment)**

1140

54

1236

298

419

1989

**Eigenvalues**

use Eigenvalue Problems

**Elastic Core-Containing Media**

1265

**Dynamic Weighing Method**

741

1096

**Elastic Foundations**

790

775

2157 778 1249  
1259

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1790 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

Elastic Half-Space			Elastomers		
2400 252		1936	2570 631		1885 1886 2097 58
2312			1651		2526 1528
Elastic Media			Elastoplastic Properties		
2490 2191 1302 413	405	1086	2260 2172	45	1349
1552 1983		1526	1059 1319		
Elastic-Plastic Properties			Electric Drives		
361	664	126	532		
	1344	1066			
		1346			
Elastic Properties			Electric Generators		
252	1345	86 837	use Electric Power Plants		
		426 997			
		2606 1347	Electric Power Plants		
		1527	791	394 25 26 887 28	
		2397	1811	1415 386 1427 208	
Elastic Waves				1146 738	
1300 171	713 974	145 136		1416 1488	
991	1034 1035	1046 1697		2548	
1301	1044 1045	1696 1827	Electric Systems		
1961	1294 1305	2446 1967	233	899	
2181	1304 1695	2447 2448	Electric Vehicles		
2421	1374	2687	Electromagnetic Properties		
	1514		1814		
	2444		Electronic Instrumentation		
Elastically Restrained Edges			1734	626 1357	
100			696		
Elasticity			Elevated Railroads		
		1789			919
Elasticity Theory		996 1107			1439
Elastodynamic Response			Enclosures		
2202		1527	1030 1031 2602 943 14	816	98 1029
			1013		1028
Elastohydrodynamic Properties			Energy Absorbers		
2594			use Energy Absorption		
Elastomeric Bearings			Energy Absorption		
	2574	1646	1880 1222	904 45 906 1637	789
		1886	1990 2092	2094 755 1426 2097	
Elastomeric Dampers			2352 2354	2354 905 1636	
831		656		2355	
Elastomeric Seals			Energy Dissipation		
			902 103 2184 1195		
	2594		2192 1873	1805	

**Abstract**

Numbers: 1-217 218-483 484-719 720-886 887-1187 1188-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Energy Methods</b>	474	1008	<b>Equivalent Sound Levels</b>
			50 1882
<b>Energy Storage Systems</b>		1639	<b>Equivalent Surface Source Method</b>
			1291
<b>Engine Mounts</b>			<b>Error Analysis</b>
2470 5562		2318 1849	1240 2501 343 2004 665 2406 2227 1408 1089
			1650 683 2175 2267 2228
<b>Engine Mufflers</b>			1690 2215 2268
142		1397	
<b>Engine Noise</b>			<b>Exact Methods</b>
281 1472	1865 2056 1397 1088		2158
381 1812	2055 1447		
	2047		
	2057		
<b>Engine Vibration</b>			<b>Exhaust Noise</b>
212 923	876		304
2323			
<b>Engines</b>			<b>Exhaust Systems</b>
1162 1114	2587		1500
1542			
<b>Equations of Motion</b>			<b>Experimental Results</b>
312 1683 1794	997 1128 1769		use Experimental Test Data
1753	1248		
1793			
<b>Equilibrium Methods</b>			<b>Experimental Test Data</b>
42			1811 1912 1404 1485 1406 1877 1618 1649
			1851 1992 2084 1925 1596 2097 2098 2049
			2134 2135 1926 2187 2538 2539
			2344 2325 2326
<b>Equipment</b>			<b>Explosion Detection (Nuclear)</b>
	2006	2639	use Nuclear Explosion Detection
<b>Equipment Mounts</b>			<b>Explosion Effects</b>
	824		2191 552 1004 1517 619
			1324
<b>Equipment Response</b>			<b>Explosions</b>
31 1142 243 24	386 37	399	
261 893 684			
731 2243 824			
891			
2241			
<b>Equivalence Principle</b>			<b>Explosives</b>
	215		563 644 646
<b>Equivalent Linearization Method</b>			
740 1691	1985 2276	828	<b>Failure Analysis</b>
	2205	1058	190 661 582 2193 184 2196 187 2659
			2030 2251 2363 597
			707

- F -

**Abstract**  
Numbers: 1-217 218-483 484-718 720-886 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Failure Detection</b>														<b>Fatigue Tests (continued)</b>				
2471 2402 2403 2404					696	2018	2289							1185				
	2444													1345				
<b>Fan Blades</b>														1525				
950		1533												2375				
<b>Fan Noise</b>														<b>Feedback Control</b>				
1581						2047								1116				
1861						2297												
<b>Fans</b>														<b>Fiber Composites</b>				
1580 951	1413 1174	525 226	517 68											340 612	2354 2355	2297 88	2149	
1581	1533 1414	875 526	727											1342		2407 998	2439	
1811	1853 1784	1415 726	1427				1957											
							2567											
<b>Fast Fourier Transform</b>														<b>Fiberglass</b>				
2012	674	526	69											2183				
	1364	2086	1089															
<b>Fast Fourier Transformation</b>														<b>Fiberscopes</b>				
use Fast Fourier Transform														176				
<b>Fatigue Life</b>														<b>Field Test Data</b>				
470 1 12 163	64 165	326 227	238 599											1630	1204			
600 41 1342	1083 164	265 836	317 258	659														
660 191 1992	1163 224	285 856	327 1188	1219														
1200 211 2222	1343 834	895 1186	1187 1218	1719														
1440 321	1603 894	1085 1566	1617 1298	2109														
1660 481	1993 1084	1625 2016	1717 1348	2439														
1720 661	2303 1524	1645 2636	1787 1438	2519														
1870 791	2373 1544	1795	1837 1718	2639														
2220 1111	2643 1564	2635	2077 1788															
2440 1341		1834	2107 1938															
2460 1371		1994	2117 2368															
	1871	2304	2367 2438															
1991	2644		2427 2618															
2221			2637 2638															
<b>Fatigue (Materials)</b>														<b>Finite Difference Technique</b>				
1530 162		835		659										862 123	84 2155	1496 2227	939	
	2642													1642		1506		
<b>Fatigue Strength</b>															1656			
use Fatigue Life																		
<b>Fatigue Tests</b>														<b>Finite Difference Theory</b>				
680 2441	1083 1084	205 236	237 438	1189										2460 1731	2002 2003		179	
2641	2343 1344	325 916	327	2369										2471 2472				
		2374 835	1346 437															
		1085 1546	1347															
														(cont'd)				

**Abstract**

Numbers: 1-217 218-483 484-719 720-806 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2290-2504 2505-2601

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Finite Element Technique (continued)</b>				<b>Flight Tests</b>		
2080	2503	2196	2168 2069			1727
2190	2673	2386	2188 2219			
2380	2683		2258 2419	<b>Flight Vehicle Equipment Response</b>		
2490			2478	2241		
2590						
<b>Finite Strip Method</b>				<b>Flight Vehicles</b>		
	983	616 1257 558		560	1085	929
					2235	
<b>Flexibility Coefficients</b>				<b>Floating Bodies</b>		
2042 1133		1137 2108		use Floating Structures		
		2377				
<b>Flexible Couplings</b>				<b>Floating Ice</b>		
510	333 794				1854	
<b>Flexible Foundations</b>				<b>Floating Ring Journal Bearings</b>		
	724	1946	1828 2049	73	2577	
<b>Flexible Rotors</b>				<b>Floating Structures</b>		
500 491 2662	223 2474 1115	486 487 2668	499		826	
700 701	493 1365 1366	1807	1409	<b>Floors</b>		
1170 1741	723 1405 1406	2667	2669	2621	1823	385
2531	1173 1565	2666			1635	1038
2661	1743					
	1813					
<b>Flexible Shafts</b>				<b>Flow-Induced Excitation</b>		
	2296		2509	use Fluid-Induced Excitation		
<b>Flexural Response</b>				<b>Fluid Amplifiers</b>		
2101	333		1889		1075	
<b>Flexural Stiffness</b>				<b>Fluid Couplings</b>		
1060		1405			1677	
<b>Flexural Vibration</b>				<b>Fluid Damping</b>		
100 91 492 1663	94 225 986 1247	618 109		use Viscous Damping		
340 111 1082 1903	1014 325 1456 1337	1168 1249				
1250 341 1532 2103	1264 625 1926 1577	1178 1259				
1660 351 1852 2153	1924 975 2386 1927	1258 2399				
1720 611 1932	2154 1655 2606	1987 1268				
1001 2332	2214 1935	2157 1338				
1261	2384 2155					
1671	2424 2605					
1941						
2161						
2411						
<b>Flexural Waves</b>				<b>Fluid-Filled Containers</b>		
970 2151 1272	944 2455		2609	790 411 783 374 1275 1946 1277 1018 1279	315 1406	79
2162	1014			1010 1951 1673 784 1675		509
				1950 2481 2613 1674 1945	2347 1278	869
				2160 2673		
<b>Fluid-Film Bearings</b>						
	580 581 1892					
	1740 761					

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2269 2280-2604 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Fluid-Induced Excitation</b>		<b>Force Generators</b>	
130 131 132 23 134 95 96 127 158 129		2243 2244	
740 391 262 133 374 485 116 377 208 349			
770 791 572 373 604 1275 346 1267 378 519			
990 951 922 503 1024 1795 606 1427 488 759			
1200 971 992 623 1254 2415 716 1737 518 939			
1490 991 1602 653 1764 736 1787 948 979			
2170 1021 1722 993 1834 1026 1947 1288 1509			
1031 1912 2593 1944 1496 2417 1788 2169			
1491 2072 2413 2364 1676 2617 1808			
1551 2142 2613 1686			
1661 1836			
1711 1896			
1841 2116			
2051 2146			
2131 2416			
<b>Fluid-Induced Vibrations</b>		<b>Forced Vibration</b>	
<b>use Fluid-Induced Excitation</b>		871 342 83 504 1535	1068 2399
<b>Fluid Mechanics</b>		492 1003 554	
	2478	1772 1063	
		1253	
<b>Fluids</b>		<b>Forcing Function</b>	
2452 1675 2347		2090	
<b>Flutter</b>		<b>Fossil Power Plants</b>	
950 881 92 43 404 415 66 1137 158 759		890 1811	1416 1287 2548
1620 961 752 1153 2275 286 2037 938 769			1427
1790 1621 872 1533 2345 726 2567 2038 929			
2040 1791 1152 1623 1526 1139			
2360 2041 1452 1666 1619			
2101 1792 2086 1869			
1902 2516 1889			
2102 2556 2039			
<b>Flywheels</b>		<b>Foundation Excitation</b>	
	1639	<b>use Base Excitation</b>	
<b>Foams</b>		<b>Foundations</b>	
942 1704 1637		220 253 1804 1805 526 1827 1828 1829	1924 1825 536 2527 2529
<b>Follower Forces</b>		1180 1740	
601 92 1334 1526		1936	
1261		1830 2530	
<b>Footings</b>		<b>Four Bar Mechanisms</b>	
250		2491	
<b>Force Apportioning Method</b>		<b>Fourier Analysis</b>	
420		973 354	1728 2319
<b>Force Coefficients</b>		1924	2138
2052 1477 1478			2658
<b>Abstract</b>		<b>Fourier Series</b>	
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2605-2691		2148	
<b>Volume 13</b>		<b>Fourier Techniques</b>	
<b>Issue:</b>	1 2 3 4 5 6 7 8 9 10 11 12	<b>use Fourier Analysis</b>	
		<b>Fourier Transformation</b>	
		430 2191 992 1383	2146 818 429
		2442	1448

<b>Fourier Transforms</b>		<b>Friction</b>	
use Fourier Transformation		960 2111	1895 1476
<b>Fracture Properties</b>		<b>Friction Bearings</b>	
1750 1721 162 1603	455		316
2121			
<b>Framed Structures</b>		<b>Friction Damping</b>	
2601	1194 2115 2136		89
	2176		
	2536		
<b>Frames</b>		<b>Friction Excitation</b>	
1990 1081 2392 883 1914 1915	977	2533	1307
2621	1913 2044 2135		
2134			
<b>Free Vibration</b>		<b>Fuel Tanks</b>	
1160 871 102 343 504 1245 616 617 608 219		1635	1537
1260	962 353 964		
1082 963			
1522 1253	1008 1259		
	1068 1379		
<b>Freight Cars</b>		<b>Functional Analysis</b>	
	64 65 206 207 1438 59	463	
	2074		
<b>Frequencies</b>		<b>Functions (Mathematics)</b>	
390			998
<b>Frequency Coefficients</b>		<b>Fundamental Frequency</b>	
2230	976	1941 1922 763 524 115 1956 2137 2138	
		2511 2152 2153 1145 2157	
<b>Frequency Domain</b>	1774		
		<b>Galerkin Method</b>	
		352 453	965 1086
		1463	969
<b>Frequency Domain Method</b>		<b>Galloping</b>	
1700 1351 1102 1773 244 1995 556 1847 2258 179		961 962 2213	1245
1731	1554 2485		
	2277		
	2219		
	2409		
<b>Frequency Equation</b>		<b>Gas Bearings</b>	
	2494	1481	589
<b>Frequency Measurement</b>	174		
		<b>Gas Turbine Engines</b>	
		891 1523	1865
<b>Frequency Response</b>		<b>Gas Turbines</b>	
1333	2465 1466 677 428 1299	1810	
	2417 818 2459		
	1688		
<b>Frequency Response Function</b>		<b>Gases</b>	
	2004		1335
	2334		
<b>Abstract</b>		<b>Gear Boxes</b>	
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2280-2504 2505-2691		330 2671	2657
<b>Volume 13</b>			
<b>Issue:</b>	1 2 3 4 5 6 7 8 9 10 11 12		

<b>Gear Couplings</b>	333	334	225	1168	<b>Graphic Methods</b>	42	163	2635	168	799
									698	
<b>Gear Drives</b>	10	331	2302	2093	324	2586	2688		708	
					2251					
<b>Gear Noise</b>	330	331								
<b>Gear Teeth</b>	2111	762		1894						
		2371								
<b>Gears</b>	330	1181	322	323	1894	325	326	327	328	329
	520	1241	1242	2113	2114		1126	707	1648	1649
	1240	2111	2112				2656	957	2368	2369
	1650	2371	2372				2676	1647		
	2370									
<b>Generators</b>	1740									
<b>Geometric Effects</b>	500	251	1032	1973		555	1686	1217	1308	
	2290	761				1075		1897	2598	
	2340	1471				1665				
<b>Geometric Imperfection Effects</b>	1042					609				
						1409				
<b>Girders</b>	1910	1251				1185	236	237	1938	1189
						2075	256	1187		
						1186				
<b>Glass</b>		833								
<b>Glass Reinforced Plastics</b>			2355							
<b>Global Analysis</b>	2263									
<b>Gradient Methods</b>					1119					
<b>Graphic Methods</b>						<b>Gyroscopes</b>	421	832	435	2576
									2575	2568
						<b>Gyroscopic Effects</b>	721		2106	1808

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>- H -</b>		<b>Heat Exchangers</b>												
half-Plane		1527			130 131 132 133 2414			2617 208 1019						
half-Space		1044			1020 1021 2412 2413			1288 2169						
Hamiltonian Principle		2144			2170									
Hammers		629												
Handbooks		use Manuals and Handbooks						Heat Generation						
Hand Tools		2534			1248			1625 1626						
Harbors		2314						Heat Shields						
Hardened Installations		1421 1252			576			Heat Transfer						
		1316			1020			1290 1171						
Hardened Structures		use Hardened Installations						Heaving						
Harmonic Analysis		980 2141			770			770			279			
990								Helical Gears						
Harmonic Balance Method		965			1240 762			1650						
Harmonic Excitation		410 1331 412 413 414 1885 1256 437 1918 89						Helical Springs						
1080 1691 992 1923 784 2435 1696 727 2598 779		1316			1523 283			Helicoidal Membranes						
2100 1821 2361		1986			940			Helicopter Blades						
Harmonic Response		1272 1403 1594			1407			use Propeller Blades						
1055 1086		427 1678 1709			1633 1154			1226			1228 1389			
Harmonic Waves		1583			1863			1584			1388 1229			
Head (Anatomy)		1573			1468 2229			1624			2559			
Helmholtz Resonators								1154 1635 1646						
Abstract		1573			1468 2229			1584			1624			
Numbers:		1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1790 1800-2046 2047-2269 2290-2504 2605-2891			1027 1028									
Volume 13														
Issue:		1 2 3 4 5 6 7 8 9 10 11 12												

<b>Hertzian Contact</b>		<b>Human Hand</b>	
2112		861	297
<b>High Frequencies</b>		<b>Human Head</b>	
	2456 2197	use Head (Anatomy)	
<b>High Frequency Excitation</b>		<b>Human Organs</b>	
2570 822		use Organs (Biological)	
<b>High Frequency Response</b>		<b>Human Response</b>	
	107	50 51 52 53 754 935 1876 537 568 49 150 861 912 903 934 2046 817 1468 569 570 911 1232 1233 1444 1877 1878 689 1570 941 1632 1573 1630 1231 2622 1633 2350 1631 1863 2351	
<b>High Speed Transportation Systems</b>			1469 1629 1879 2349
	918 1849		
<b>Hilbert Transforms</b>		<b>Human Tolerance</b>	
	1124		155
<b>Hill Equation</b>		<b>Hunting Motion</b>	
	1553	20 921 273 2074 1850	
<b>Hitches</b>		<b>Hydraulic Equipment</b>	
use Drawbars		10 1224 1025	9
<b>Hole-Containing Media</b>		<b>Hydraulic Systems</b>	
1052 984 1234 2024	356	998	305 546 1027 1598 1026 1147
<b>Holes</b>		<b>Hydraulic Valves</b>	
1052			1485
<b>Holographic Techniques</b>		<b>Hydrodynamic Bearings</b>	
1090 171 172 1730 1091 1312	1926 447 2016 2647 2156	1482	
<b>Honeycomb Structures</b>		<b>Hydrodynamic Damping</b>	
	755	524 356	
<b>Hoses</b>		<b>Hydrodynamic Excitation</b>	
	1025	1027	770 71 1912 1513 1254 1595 1636 927 418 1499 1210 2072 1954 1856 1597 2188 2380 2314 2066 2067 2578 2317
<b>Housings</b>		<b>Hydrofoil Craft</b>	
331 1181		2081 404	279
<b>Hovercraft</b>		<b>Hydrophones</b>	
use Ground Effect Machines		1722 1735 2646 2495	
<b>Hulls</b>			
991			

---

Abstract  
Numbers: 1-217 218-483 484-719 720-866 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2269 2290-2504 2505-2691

Volume 13

---

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

---

<b>Hydrostatic Bearings</b>			<b>Induction Motors</b>		
300		318	1360	1693	699
		1238			
<b>Hysteretic Damping</b>			<b>Industrial Facilities</b>		
2192	425 1066	1758 2199	1391 392 813	395 816 247 628 629	
2612	655		2431 2623	815 2006 887 2548 1879	
	1495			1515 907	
				1975	
<b>Ice</b>			<b>Industrial Noise</b>		
	1854		use Industrial Facilities and Noise Generation		
<b>Impact Dampers</b>			<b>Inertial Forces</b>		
use Shock Absorbers				2395	
<b>Impact Force</b>			<b>Influence Coefficient Matrix</b>		
	2273	818	use Influence Coefficient Method		
<b>Impact Noise</b>			<b>Influence Coefficient Method</b>		
	2184		700 871 2474 1365		
<b>Impact Response</b>			2020 1901		
1350 611 152 403 574 35	357 58 359		2661		
2081 1072 563 974 355	467 68 2179				
1823 1934 665	757 108 2589		<b>Initial Deformation Effects</b>		
	2125 847 958		1270 361 762 1264		2398 339
	2145 2387 1238				
	2235 2408				
<b>Impact Shock</b>			<b>Initial Value Problems</b>		
	636		use Boundary Value Problems		
<b>Impact Testing</b>			<b>Instrumentation</b>		
use Impact Tests				1748	
<b>Impact Tests</b>			<b>Instrumentation Response</b>		
	2583	1516 837			1357
<b>Impedance Technique</b>			<b>Instruments</b>		
1571 1513		1499	use Instrumentation		
2493					
<b>Impellers</b>			<b>Integral Equations</b>		
1 503	877 488		1560 1552 1373 194 1135		97 848
			2270 1772 2264		847
<b>Impulse Intensity</b>			<b>Integration</b>		
2432				1555	
<b>Interaction: Ice-Structure</b>			<b>Interaction: Rail-Vehicle</b>		
				1604	
<b>Interaction: Rail-Wheel</b>			1203		206 748
20 691 272 183 34 65				207 2099	
690 921 1202 2553 274 945				1437	
					(cont'd)

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2604 2605-2891

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Interaction: Rail-Wheel (continued)</b>		<b>Interface: Solid-Fluid</b>		
920 1852 1434 1355				1698
2332 1435				
<b>Interaction: Rotor-Casing</b>		<b>Interface: Solid-Solid</b>		
	2508	1303	2446	848
<b>Interaction: Rotor-Foundation</b>		<b>Interferometers</b>		
2530	2527 2528 2529	171		
<b>Interaction: Rotor-Stator</b>		<b>Interferometric Techniques</b>		
281	39	1090 2462	66 447	2459
			1926	
			2156	
<b>Interaction: Shiphull-Machinery</b>		<b>Interior Noise</b>		
	37 928	940 2321	1213 2324 2555 936	118
<b>Interaction: Shock Waves - Boundary Layer</b>		2470		2318
1054				
<b>Interaction: Soil-Structure</b>		<b>Internal Combustion Engines</b>		
400 252 253 2504 655 1826 637 468 29		1884	2457	
732 793 885 1936 1827 1828 819				
1982 2043 1785 2286 2628 1359			1404	2207 358
2313	1779			768
				2518
<b>Interaction: Solid-Fluid</b>		<b>Inverse Variational Principle</b>		
1723	1677		1145	
<b>Interaction: Structure-Fluid</b>		<b>Isolation</b>		
390 411 362 263 264 365 196 1067 408 269			303	2677
2390 2481 842 363 364 375 736 2257 418 369				
2410 2541 922 803 424 2165 2256 2317 1018 469		<b>Isolators</b>		
2611 1602 2123 544 2255 2316 1918 2409			566 2097 2098	
2673 2254 2285	2188		756	
	2258		2096	
<b>Interaction: Structure-Medium</b>		<b>Iteration</b>		
	2258	1561 1562	2054 1385 2496	
<b>Interaction: Vehicle-Guideway</b>			2495	
	918			
<b>Interaction: Vehicle-Terrain</b>			- J -	
902 903	275			
<b>Interaction: Vehicle-Tire</b>		<b>Jet Engines</b>		
	578	281 212 1413 1414 1505	1447	1449
		1611	2567	
<b>Interaction: Wheel-Pavement</b>		<b>Jet Noise</b>		
290 441	44	1450 1211	1613	1966
		1860 1861		1449

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2289 2290-2604 2605-2881

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Joints (Junctions)</b>	<b>Large Amplitudes</b>
601      1653      184      335      2376      597      598      2589	2411      1282
761      2373      794      1255      2177      958	
1991      1244      1895      2377      2588	
2374      2115	
2375	
<b>Journal Bearings</b>	<b>Lasers</b>
760      2581      72      73      74      75      76      587      318      69	2462
1480      2582      493      2584      585      486      2527      588      499	
2580      1643      2365      586      2577      2108      509	
2583      2505      2366      2578      2109	
2579	
<b>Lateral Response</b>	<b>Lateral Vibration</b>
2331	521      2122
	2381
	484      5      1576
	1904      945
	1025
<b>Lathe</b>	
	2058
<b>- L -</b>	
<b>Launch Vehicles</b>	
	858
<b>Laboratory Test Data</b>	
1630      1604      1488	
<b>Lagrange Equations</b>	<b>Launchers</b>
	48
	988
<b>Lamb Waves</b>	<b>Launching Response</b>
1701	557      559
<b>Laminates</b>	<b>Lawn Mowers</b>
use Layered Materials	814
<b>Lanczos Method</b>	<b>Layered Damping</b>
1663	2384      1336      2219
<b>Landing Fields</b>	<b>Layered Materials</b>
use Aircraft Landing Areas	1250      1341      152      413      104      1265      1016      387      998      999
	1310      1511      412      533      414      1305      2026      1937      1039
	2031      1682      1493      2126      2407      1269
<b>Landing Gear</b>	2181      1563
1462      947	1923
	2433
<b>Landing Impact</b>	<b>Leading Edges</b>
use Landing and Impact Shock	404
<b>Landing Shock</b>	<b>Leaf Springs</b>
use Landing and Impact Shock	61
<b>Landing Simulation</b>	<b>Least Favorable Response Method</b>
use Landing and Simulation	2249
<b>Laplace Transformation</b>	<b>Least Squares Method</b>
1771      192      2024      1906      2298      199	850      202      445
	852      1365      639
<b>Abstract</b>	
Numbers: 1-217      218-483      484-719      720-866      867-1167      1168-1402      1403-1574      1575-1700      1800-2046      2047-2289      2290-2604      2505-2691	
<b>Volume 13</b>	
<b>Issue:</b>	1      2      3      4      5      6      7      8      9      10      11      12

<b>Liapunov's Method</b>			<b>Loosening</b>		
use Lyapunov Functions				1694	958
<b>Life Line Systems</b>			<b>Loss Factor</b>		
	804 1785 1594	2627 798	1100		
<b>Limit Analysis</b>			<b>Low Frequencies</b>		
	422	125	600 1231 562 1263 1880 2651 2570	1036 2507	1309
<b>Line Source Excitation</b>			<b>Lubrication</b>		
	993		70 2571 2110	1813 2114 1895 2113 2594	1237 2108
<b>Linear Analysis</b>			<b>Lumped Mass Method</b>		
use Linear Theories			use Lumped Parameter Method		
<b>Linear Damping</b>					
use Viscous Damping					
<b>Linear Systems</b>			<b>Lumped Parameter Method</b>		
160 1561 472 423 464 405 1156 457 2208 1070 2022 1333 1376 2480 1773			970 1913 2380 2503	1755 1376 767 1757	2329 2599
<b>Linear Theories</b>			<b>Lyapunov's Method</b>		
	1801 2432	375 1056 1395 2406	2480	844 845	1377
<b>Linings</b>		1114 2065	1287 1678		
				- M -	
<b>Linkages</b>			<b>Machine Diagnostics</b>		
2590 601	1484 335 1655		use Diagnostic Techniques		
<b>Liquefaction</b>		733	<b>Machine Elements</b>		
			use Machinery Components		
<b>Liquid Filled Containers</b>			<b>Machine Foundations</b>		
use Fluid Filled Containers			1830	535	2539
<b>Liquid Propellant Rocket Engines</b>		1466	858		
			<b>Machine Noise</b>		
			use Machinery Noise		
<b>Locomotives</b>		2325 746	<b>Machine Tools</b>		
1202 1203			880 231 232 2293 1400 531 1402 1401 1182	756 2307 1238 9 2306 2377 1418 319 2376 2058 2059	
<b>Longitudinal Response</b>		1025 1455	<b>Machinery</b>		
			191 1361 2281		
<b>Longitudinal Vibration</b>		2597 1658			
1831 1462					

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2601

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Machinery Components</b>					<b>Mass Half-Space Systems</b>			
211	164		2427	2179				2298
	1564							
<b>Machinery Foundations</b>					<b>Mass Matrices</b>			
<i>use Machine Foundations</i>							1136	
<b>Machinery Noise</b>					<b>Mass-Spring Systems</b>			
2690	302	1244 1515		2179				2199
	1112	2184			<b>Mass Transportation</b>			
<b>Machinery Vibration</b>					920			
2690	1113	535 1116 2017	718		<b>Material Damping</b>			
					660 1171	833	625	1658 1339
<b>Machining</b>				678	1340		655	2399
<b>Magnetic Bearings</b>					<b>Materials</b>			
2572						2624	2196	
<b>Magnetic Damping</b>				298	<b>Materials Handling Equipment</b>			
					2061			2308
<b>Magnetic Suspension Techniques</b>					<b>Mathematical Modeling</b>			
550 301			36	918	<i>use Mathematical Models</i>			
<b>Magnetoelasticity</b>					<b>Mathematical Models</b>			
	2453 2454				10 461 462 203 554	35 266 197 458 229		
<b>Manipulators</b>					270 1931 882 223	305 846 297 748 749		
					750 2031 2032 1133	2275 1076 1137 758 1129		
<b>Marine Engines</b>				1548 1549	880 2212 1803	1206 2167 2218 1299		
					1380 2372 2273	1226 1569		
	324				1520 2493	2206 1789		
	2054					2523	2336	2219
								2419
<b>Marine Propellers</b>				229	<b>Matrix Methods</b>			
	2333 524		1576		2020 2272 2143			1136 1127 1068
<b>Marine Risers</b>					<b>Maximum Entropy Method</b>			
280 1912			896 897 898			1364		
740					<b>Mean Square Response</b>			
<b>Mass Beam Systems</b>					2140 903			1058
			1246 1657		<b>Measurement Instruments</b>			
<b>Mass Coefficients</b>					<i>use Measuring Instruments</i>			
560 313			1137	929	<b>Measurement Techniques</b>			
2170 603				1129	170 1271 172 1273 144 175 176 667 428 169			
1133					1420 1531 272 1413 274 2005 636 837 478 669			
<b>Mass Condensation Method</b>					1690 1781 642 1533 334 2105 666 2007 668 1729			
			2136		1730 1971 1702 1993 1414 2175 2006 2227 1088 2009			
					1820 2281 2062 2233 1534 2585 2426	2008 2229		
						(cont'd)		

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Measurement Techniques (continued)</b>			<b>Membranes (Structural Members)</b>		
2320 2301 2232 2523 1734	2456	2228 2359	2142 2393 454 2025	1917 2138	
2360	2573 2004	2248			
2420		2648	<b>Metal Working</b>		
2650			2060	1818	
<b>Measuring Instrumentation</b>				2588	
use Measuring Instruments			<b>Metals</b>		
<b>Measuring Instruments</b>			2440	645 2636	
670 2001 1092 303 674 435 436 177 668 1099					
2000 2461 1352 1093 1094 1095 666 1097 1098 1529			<b>Method of Characteristics</b>		
2681 1732 1003 1354 1355 1356 1727 1528 1999			2225 1496		
2062 1533 1724 1725 1726 1997 1998 2459			<b>Method of Harmonic Linearization</b>		
2672	2645 1996	2008	380		
		2248			
		2458	<b>Method of Initial Functions</b>		
<b>Measurement Techniques</b>			1260 102	987	
use Measurement Techniques					
<b>Mechanical Admittance</b>			<b>Method of R-Functions</b>		
981	1276			2489	
<b>Mechanical Drives</b>			<b>Method of Steepest Descent</b>		
2303 2054		1587 2688	use Steepest Descent Method		
2293 2304		1647	<b>Method of Stochastic Averaging</b>		
<b>Mechanical Elements</b>			2033	1066	
	856		<b>Method of Weighted Residuals</b>		
<b>Mechanical Impedance</b>				1959	
610 621 682 1103 2344		2096 767 878	<b>Mindlin Theory</b>		
1400 681 1362 1483		2437	983	1268	
1401 1402 2463			<b>Mines (Excavations)</b>		
1271			641 642	2008 1469	
<b>Mechanical Properties</b>			2311	2639	
1092					
<b>Mechanical Reliability</b>			<b>Minicomputers</b>		
use Reliability			752		
<b>Mechanical Systems</b>			<b>Minimax Technique</b>		
840	1555		1320	2666	
<b>Mechanisms</b>			<b>Mining Equipment</b>		
2491 2272 1183		1556		627	
2492		2486	<b>Missile Launchers</b>		
<b>Membranes</b>				2118	
use Membranes (Structural Members)			<b>Missile Launching</b>		
				2118	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2289 2290-2504 2605-2601

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Missile Silos</b>	<b>1252</b>	<b>Mode Shapes</b>	<b>110 11 982 63 1924 985 986 337 558 1299</b>
			<b>350 1661 1262 223 1005 1006 417 878 1559</b>
<b>Missiles</b>			<b>1010 1831 1332 323 1905 1246 1247 1118 2159</b>
<b>2560</b>	<b>294 415 576 567 1628</b>		<b>2150 1931 1672 1193 1925 1776 1657 1428 2539</b>
			<b>2510 2091 1253 2115 1926 1917 1678</b>
			<b>2361 1663 2266 1848</b>
<b>Mixed Element Technique</b>			<b>2393 1898</b>
	<b>982</b>		<b>2523 2058</b>
			<b>2648</b>
<b>Mobility Functions</b>		<b>Model Testing</b>	
	<b>1124</b>	<b>540 541 543</b>	<b>757 2539</b>
<b>Mobility Method</b>			<b>1583</b>
<b>1140 2232 2493</b>	<b>1729</b>		
<b>Modal Analysis</b>		<b>Model Tests</b>	
<b>2230 461 322 203 534 405 6 1607 678 679</b>		<b>use Model Testing</b>	
<b>2681 472 1374 1425 1136 2207 1778 1069</b>			
<b>2612 1755 1156 2267 2268 1209</b>			
	<b>1756 2299</b>		
	<b>2509</b>		
<b>Modal Balancing Technique</b>		<b>Moment Coefficients</b>	
<b>2661 2474 1365</b>			<b>1477 1478</b>
<b>Modal Constraint Method</b>		<b>Monitoring Techniques</b>	
<b>2483</b>		<b>190 191 2472 704 695 676 447 188 189</b>	
		<b>1370 211 2672 1544 705 706 707 448 449</b>	
<b>Modal Damping</b>		<b>1750 1371 1744 1545 1546 1117 718 839</b>	
	<b>1205</b>	<b>2670 1751 1745 1746 1547 1368 1369</b>	
		<b>2671 2476 1747 1568 1749</b>	
			<b>1748</b>
<b>Modal Densities</b>		<b>Monte Carlo Method</b>	
<b>1100</b>			<b>1774 1656</b>
<b>Modal Superposition Method</b>			<b>2276</b>
<b>821 782 843 2274</b>	<b>2136</b>	<b>1009</b>	
<b>822</b>			
<b>Modal Synthesis</b>		<b>Moorings</b>	
<b>2501</b>	<b>196</b>	<b>1069</b>	<b>2335 607</b>
<b>Modal Tests</b>		<b>Motorcycles</b>	
	<b>534</b>	<b>2089</b>	<b>754 1205</b>
	<b>1104</b>		<b>1848 1204</b>
<b>Mode Approximation Technique</b>		<b>Motor Vehicle Engines</b>	
	<b>1324 1315</b>		<b>73</b>
<b>Mode Displacement Method</b>		<b>Motor Vehicle Noise</b>	
	<b>1756</b>		<b>2551 1842 913 914 1165</b>
<b>Mode Modification Method</b>			<b>1164</b>
<b>560</b>		<b>Motor Vehicles</b>	
			<b>1634 1846 1607</b>

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2280 2290-2504 2605-2691

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Motors</b>		- N -
1360 161 1042 1693 1694 2525 2526	528	
1092	2524	
<b>Mountings</b>		<b>Nastran (Computer Programs)</b>
5562	756 1177	1150 1151 364 2275 556 2037 2038 2039
	2526	2040 2321
		2590
<b>Moving Loads</b>		<b>Natural Frequencies</b>
730 2191 12	1854 775 1906 2127 8 1659	110 11 92 63 4 765 596 87 38 109
1820 1002	1984 2385 2397 1588 2129	350 101 112 113 84 985 986 337 528 1249
1890 1682		1000 1261 982 223 114 1005 1006 417 558 1299
2122		1010 1661 1262 323 124 1205 1246 867 878 1549
		1800 1831 1662 1193 234 1905 1776 987 1028 1559
		1910 1931 1672 1913 384 1925 1926 1257 1118 2159
		1940 2061 1922 1943 454 2115 2266 1287 1178 2269
		2150 2361 2082 2393 1904 2386 1657 1278 2239
<b>Mufflers</b>		2510 2132 2483 1924 1917 1428 2599
1470 1471 1472 393 304	1397	2202 2523 2054 2137 1678
1883 1234		2294 2197 1888
1884		2484 2347 1898
		2494 2058
<b>Multibeam Systems</b>		2648
1021 373 344 345	377 378	
	1288	
<b>Multidegree of Freedom Structures</b>		<b>Natural Vibrations</b>
use Multidegree of Freedom Systems		492 1937
<b>Multidegree of Freedom Systems</b>		<b>Newmark Method</b>
820 1761 572 1713 1524	2496	1135
2300 2493 1714	898 409 829	
		<b>Noise Barriers</b>
		810 811 1882 633 2624 55 146 147 808 149
		1973 2545 807 1308 809
		919
<b>Multifrequency Testing Techniques</b>		<b>Noise Control</b>
2240		use Noise Reduction
<b>Multiplane Balancing Technique</b>		<b>Noise Generation</b>
1741		2290 311 82 283 394 135 226 137 328 19
<b>Multipocket Bearings</b>		2340 2051 392 813 395 816 887 628 329
1644		2551 812 1033 555 926 1307 1418 269
<b>Multipole Analysis</b>		1202 1413 815 1196 1487 1568 1179
141		1512 2323 1225 1486 2307 1818 1469
		1952 2333 1586 2547 1509
		2332 2623 1879
<b>Multistory Buildings</b>		<b>Noise-Induced Excitation</b>
1990 731 1822 2063	2536	1497
1081 2392		
1921		
<b>Musical Instruments</b>		<b>Noise Measurement</b>
		670 1451 1202 143 144 815 1446 1877 908 169
		1810 1531 1352 753 814 1215 1616 2007 1088 909
	2648	(cont'd)

**Abstract**  
**Numbers:** 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2269 2290-2604 2605-2601

**Volume 13**

**Issue:** 1 2 3 4 5 6 7 8 9 10 11 12

<b>Noise Measurement (continued)</b>		<b>Noise Transmission</b>	
2320 2341 1732 1413 914 1445 1976	1858	1294	907 98
2342 1443 1204 1505 2006			108
1214 2046			2338
1414 2546			
1464			
1574			
2084			
2324			
<b>Noise Meters</b>		<b>Nomographs</b>	
use Sound Level Meters		2632	2358
<b>Noise Prediction</b>		<b>Noncontacting Probes</b>	
1390 931 932 143 1154 1155 1206 1877 1228		use Proximity Probes	
1391 1212 853 1864 1505 1216	1858		
1612 2073 2184 2555 2546			
<b>Noise Propagation</b>		<b>Nondestructive Testing</b>	
use Sound Propagation		use Nondestructive Tests	
<b>Noise Reduction</b>		<b>Nondestructive Tests</b>	
520 281 282 13 14 55 146 147 228 9		440 441 1362	1304 1736 1107 1348
530 331 302 393 304 245 546 247 538 19		660 2012	2444 1796 1797 1798
630 631 392 533 314 525 816 627 628 39			2467
910 1181 602 613 564 815 866 887 1958 149			
940 1211 622 813 1174 915 1026 1027 2318 529			
1420 1471 632 943 1184 1025 1786 1207 2338 629			
1450 1861 812 1433 1244 1035 2056 1217 2548 879			
1470 2591 1032 1613 1614 1445	1397		
1780 1242 1703 1704 1515	1447		
2690 1432 1843 1784 1955	1467		
1472 1863 1844 1975	1607		
1512 1883 1974 2055	1859		
1842 1973 2174 2085			
1862 2563 2184 2305	2337		
1972 2534	2677		
2182 2624			
2552			
<b>Noise Shielding</b>		<b>Nonlinear Analysis</b>	
1613 1614		use Nonlinear Theories	
1703			
<b>Noise Source Identification</b>		<b>Nonlinear Damping</b>	
330 2431 82 2233 694 2325 1306 137 2658 2319		1105	
1050 1542	1957		
2470			
<b>Noise Tolerance</b>		<b>Nonlinear Programming</b>	
50 911 913 934 935	49	1543	
941 1283			
1231			
<b>Abstract</b>		<b>Nonlinear Response</b>	
Number: 1-217 218-483 484-719 720-865 867-1167 1168-1402 1403-1674 1675-1799 1800-2046 2047-2269 2280-2504 2605-2691		361	1064 965 966
<b>Volume 13</b>			2484 1065 1766
Issue: 1 2 3 4 5 6 7 8 9 10 11 12			968 969
			2069
		<b>Nonlinear Structures</b>	
			2189
		<b>Nonlinear Systems</b>	
		1320 1331 192 403 464 415 406 1377 828 409	
		1760 1551 402 1773 1074 1325 2276 1907 1058	
		1770 1561 1072 2023 1334 2205	2387
		1782 2033	
		2302	
		<b>Nonlinear Theories</b>	
		230 1281 22 463 4 2265 1986 7 198 1199	
		410 2411 2442 1043 864 2206 1387 1598 2509	
		1134 2278	
		<b>Nonlinear Vibrations</b>	
		1330 1492 1763 1495 2166 647	
		1933	

<b>Nonsynchronous Vibration</b>		<b>Nuclear Weapons Effects</b>	
1710	2507 2578	1252 2243	1316
<b>Normal Density Functions</b>		<b>Numerical Analysis</b>	
1934		90 1561 2 403 624	2158 199
<b>Normal Modes</b>		2540 1771 1382 1383 2114	1559
390	1123	1772 2113	
<b>Nozzles</b>		<b>Numerical Methods</b>	
1450		311	2366
<b>Nuclear Explosions</b>		871	
1252	1356	<b>Nutation Damper</b>	
<b>Nuclear Fuel Elements</b>		832	1716
22		<b>Nuts</b>	
262			958
<b>Nuclear Power Plants</b>			<hr/>
60 891 242 253	25 26 267 18 239		- O -
120 542 893	735 266 737 28 399		
260 802 1353	785 1166 1167 468 889		
400 892	1425 1416 688 1539		
2070 2412	1495 1426 788 2069		
	1545 888 2619		
	1825 1198		
	1835 1488		
	2068		
<b>Nuclear Reactor Containment</b>		<b>Off-Shore Structures</b>	
1201	735	1840 271 1332 1603 894 895 706 547 688 739	
<b>Nuclear Reactor Components</b>		2250 2071 2072 1604 766 1837 1428 1839	
120 31 372 23 24	25 266 347 258 269	2550 1836 2317 1838	
1200 261 862 263 264	265 346 1677 268 1149	1908	
1600 1661 1602 623	344 365 1737 1678 1199		
2172 763 444 545			
1353 734 1715			
1544 2315	1679		
2475	1939		
<b>Nuclear Reactor Safety</b>		<b>Oil Film</b>	
540 541 543 734			2108
<b>Nuclear Reactors</b>		<b>Oil Film Bearings</b>	
30 81 22 1823 544	1826 27 1368 29	2505	487
180 1601 1942 1833 764	2316 187 2168 1009	507	
270	1943 1834		
2070			
2549	1289		
<b>Nuclear Waste Depositories</b>		<b>Oil Whip Phenomena</b>	
2540		490	
<b>Abstract</b>		<b>Oil Whirl Phenomena</b>	
Numbers: 1-217 218-483 484-719 720-966 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2200 2200-2604 2605-2601		584	487 488
<b>Volume 13</b>		<b>One-Degree-of-Freedom Systems</b>	
<b>Issue:</b>	1 2 3 4 5 6 7 8 9 10 11 12	1121	
		<b>Optical Measuring Instruments</b>	
		2001	
		<b>Optical Methods</b>	
		2647	2459
		<b>Optical Probes</b>	
		2001	

<b>Optimization</b>							<b>Panels</b>							
880 1141 232 903 854		846		859			980 1041 1792 2343	774	285	246	1667	98	979	
1411 1242 1133 1874		1386		1789			1790 1791 2142	1034	995	1666	2177	978	1919	
1881		2214		2556			1920 1921 2602	1294	1255			1218	2139	
							1990 2141						1918	
<b>Optimum Control Theory</b>							2140							
		1634					2650							
<b>Optimum Damping</b>							<b>Parameter Identification Technique</b>							
			1875				850 201 202 203	244	465	306	1137	1138	679	
<b>Optimum Design</b>							2550 1101 422 1563	694	595	316	1867	2278	2279	
1320 2281	153	1454	975		1318		2580 1221	1773	1774	1775	1806	2277	2559	
1900		2093	1145		2238		2583							
2680							<b>Parametric Excitation</b>							
<b>Orthotropic Plates</b>							1120 2021 452 1073	2194	1395	1436	2517			
use Orthotropism and Plates							1240 2302 1763		2625	2516				
<b>Orthotropism</b>							1550							
1670 1922 1263	104	115	2396		1928	2399	1650							
			994				<b>Parametric Resonance</b>							
<b>Oscillating Conveyors</b>					2308		2130 501				1776			
							2131							
							2391							
<b>Oscillation</b>							<b>Parametric Response</b>							
451 562		1075					780	1023	1094	1095	1946	897	898	
1141 1042		1535					2515							
1551 2482							<b>Parametric Vibration</b>							
<b>Oscillators</b>							650 501				1065	2027		
1121 1062	1074	2435		827										
2032		2434					<b>Passive Isolation</b>				2565			
2652														
<b>Overdamping</b>					2208		<b>Pasternak Foundations</b>							
											2397	2129		
							<b>Pavements</b>							
							470 441				1107			
								<b>Penalty Technique</b>						
								453						
							<b>Pendulums</b>				954		1769	
<b>Packaging</b>					635		<b>Penetration</b>				644	645	646	2198
<b>Packaging Materials</b>							<b>Periodic Excitation</b>				966	227	2358	1059
							1070 352 723 2654				1626	1237		1829
							1560 2612 1013				1946	1667		2029
							1710				2607	2449		

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2269 2290-2504 2506-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Periodic Response</b>		<b>Pipe Whip</b>	
550 2231 252 2143 204 2493	406 2577 358 89 1136 768 1489 1328 2129 1378 2379 2378	1393	2619
<b>Periodic Structures</b>		<b>Pipeline Systems</b>	
990 992 993 1120 1023 1073 2203	1068 1379 1759 1909	use Pipelines	
<b>Perturbation Theory</b>		<b>Pipelines</b>	
2481 452 963 2442	2185 896 357 78 1329 1377 1128 2257 1328	370 371 1022 243 794 255 26 797 368 799 800 2642 253 1024 795 796 1687 798 1149 1983 1504 1495 896 2417 1688 2419 1785	2418
<b>Phase Effects</b>		<b>Pipes (Tubes)</b>	
1720		140 621 622 793 1284 375 786 127 128 789 790 781 792 1393 1954 785 1286 787 208 1499 1500 1501 1952 1503 2414 1285 1796 1287 788 1689 2171 1953 1505 1896 1497 1018 2609 2615 2416 1797 1498	
<b>Phase Velocity</b>			2616 1798
	1507		2618
<b>Photoelastic Analysis</b>		<b>Piping Systems</b>	
1350 1372 2223 2224	2016	791 372 393 1544 801 802 623 2614 1502 803 2042 1283 2172	376 367 258 369 1686 1907 2619
<b>Photographic Techniques</b>		<b>Plain Bearings</b>	
	2554		2109
<b>Piers</b>		<b>Plane Mechanisms</b>	
1190		2680	
<b>Piezoelectric Transducers</b>		<b>Plastics</b>	
173	1998		147
<b>Piezoelectricity</b>		<b>Plate Girders</b>	
	1965		1185 1186 1188 1189
<b>Pile Drivers</b>		<b>Plates</b>	
	2547	100 101 102 103 104 105 106 107 108 99 110 111 112 113 114 115 116 117 358 109 350 351 352 353 354 355 356 237 618 349 450 981 982 563 434 615 616 357 978 469	
<b>Pile Driving</b>		990 991 992 613 614 625 776 617 988 539 1000 1001 1052 983 644 775 986 777 998 619	
<b>Pile Foundations</b>		1100 1261 1262 993 984 985 996 987 1268 989	
732	536	1150 1271 1272 1003 1004 1265 1256 997 1668 999	
<b>Pile Structures</b>		1260 1671 1672 1263 1034 1765 1266 1257 1928 1029	
	884 885 1836	1270 1691 1922 1273 1264 1925 1926 1267 1938 1049	
<b>Pipe Resonators</b>		1670 1991 1932 1923 1294 1935 2146 1667 2158 1259	
391	1499	(cont'd)	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Plates (continued)</b>		<b>Power Transmission Systems</b>		
2150 2151 2152 1933 1924 2145 2156 1917 2398 1269		230 831	1417	879
2400 2401 2332 2153 1934 2155 2396 1927 2448 1669		530 1181	1587	
2402 2403 1984 2395 2426 1937	1929			
2453 2144 2405 2606 2147	2149			
2603 2294 2605	2157	2279		
2154	2397	2399		
2404		2489		
2604				
<b>Pneumatic Dampers</b>		<b>Precast Concrete</b>		
	214		806	
<b>Pneumatic Equipment</b>				
1470				816 247
<b>Pneumatic Isolators</b>		<b>Pressure Dam Bearings</b>		
2210		1813	1406	
<b>Pneumatic Tires</b>		<b>Pressure Regulators</b>		
	1476	758 309	2591	
<b>Pogo Oscillation</b>		<b>Pressure Vessels</b>		
use Pogo Effect		1832	444 265	257 258 539
		1544 2475	447	1599
<b>Point Source Excitation</b>		<b>Prestressed Concrete</b>		
710 991 993	1306	138		
980	1676	1918		
		1988		
<b>Polymers</b>		<b>Principle of Virtual Work</b>		
1340	1343 1474	1536		1248
<b>Polynomial Analysis</b>		<b>Printing</b>		
	2494			247
<b>Pontoon Bridges</b>		<b>Prismatic Bodies</b>		
	728	451 2383		2389
<b>Porous Materials</b>		<b>Probability Density Function</b>		
1511	145 1086	2630		
<b>Power Generators (Electric)</b>		<b>Probability Theory</b>		
use Electric Power Plants		260 191 243 2284 735	957 2358 159	
		1180 2193		
<b>Power Plants (Facilities)</b>		<b>Proceedings</b>		
use Electric Power Plants		210 211 2062	1394	716 1157 208 209
		1780		1158 1159
<b>Power Series Method</b>				1568 2309
121	2487			2688
<b>Power Spectra</b>		<b>Projectile Penetration</b>		
1430	178		644 645 646	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

**Propellant Tanks**

2013

---

- Q -

---

**Propeller Blades**

1720	311	1152	953	524	1175	2557	939
2340		2102	1153	874	1585		1229
			1463	954			
			1583	1624			
			2344				

**Quadratic Damping**

2095

**Propeller Induced Excitation**

1532 116

**Quartz Resonators**

107

**Quasilinearization Technique**

850 859

**Propeller Noise**

931	143	1615	1616
2341	283		
	1863		

---

**Propellers**

1720 931 555 1576 2557

**Racks**

1916

**Proximity Probes**1726 2457 2458  
2456**Radiation Efficiency Method**

1047

**Pulleys**

2300

**Rail Transportation**

917

**Pulse Excitation**

1270	801	612	2403	374	1315	1556	1687	2298	1669
1670		1762		1324		2396		1919	
1680		2402		1654					
1900				2404					
				2424					

**Railroad Cars**

690	691	183	34	35	206	207	1438	59
1850	921	273	64	65	1436	1437		1249
		2653	1434	1435				
			2564					

**Railroad Tracks**

2090 1852 2075 256 1659

**Railroad Trains**

20	1851	715	549
	23^1		1849

**Pulse Test Method**

2011 2242

**Railroad Transportation**  
*use Rail Transportation*

804

**Railroad Vehicles***use Railroad Trains*

10	591	582	3	504	515	1026	587	228	9
520	2291	602	473	1354		1416		508	519
								518	529
								528	839
								1108	1179
								1538	
								1738	

**Rails***use Railroad Tracks***Railway Vehicles***use Railroad Trains***Abstract**

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Railway Wheels</b>		<b>Receptance Method</b>										
1541			2156									
<b>Random Decrement Technique</b>	679	<b>Reciprocating Compressors</b>										
		1814	536									
<b>Random Excitation</b>		<b>Reciprocating Engines</b>										
160 1691 1782 2033 1344 165 1066 407 1058 739		1815 1816 1397										
310 2021 2063 1524 1325 1346 1087 1628 829			2057									
980 2141 2643 1964 1345 1626 1347 1758 1299			2217									
1430 2004 1985 2066 1357 2598 2259												
1760 2284 2205 2206 1667												
2030 2276		<b>Rectangular Beams</b>										
2150			1899									
2220												
2260		<b>Rectangular Bodies</b>										
		2202	1294									
<b>Random Loads</b>	159		1326									
		<b>Rectangular Membranes</b>										
<b>Random Noise</b>			2138									
40		<b>Rectangular Panels</b>										
		1920	1666									
<b>Random Parameters</b>	1759	<b>Rectangular Plates</b>										
		110 351 1262 983 434 985 616 987 108 1929										
<b>Random Response</b>		1270 1922 1263 984 1765 776 2157 618										
200 2231	1136 427 828	2150 2152 2153 1264 2155 986										
2140	827 1728	2154	778									
	1988	2604	1668									
			2158									
<b>Random Vibration</b>		<b>Recursive Methods</b>										
2310 681 682 443 1074 1385 416	178 439	1123	2197									
2630 1072 683 1834	626											
1712 2194												
1822 2464		<b>Reduction Methods</b>										
		2490 1381 842	195 2496 2267 2268									
<b>Rapid Transit Railways</b>			2265									
1251	2385		2485									
		<b>Re-Entry Vehicles</b>										
		563										
<b>Rayleigh Method</b>		<b>Regression Analysis</b>										
	763 984		1346 1347									
<b>Rayleigh-Ritz Method</b>												
111 2153 964 995	988 109	<b>Regulations</b>										
1001 2154 2155			866									
<b>Rayleigh Waves</b>	1977		1398 1399									
			1606									
			2046									
<b>Real Time Spectrum Analyzers</b>		<b>Reinforced Concrete</b>										
1420 1091 2002	674	440 1081 882 883 384 125 2286 27 2168 619										
2460		2601 1962 1963 2064 1915	267									
		2392 2133 2134 2135	2589									
<b>Abstract</b>												
Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2604 2605-2801												
<b>Volume 13</b>												
Issue:	1	2	3	4	5	6	7	8	9	10	11	12

<b>Reinforced Plastics</b>		<b>Reverberation</b>	
	995		815
<b>Reinforced Plates</b>		<b>Reverberation Chambers</b>	
991	113	573	2005
<b>Reinforced Shells</b>			2238 1309 2429
	2166	2168	<b>Reviews</b>
<b>Reinforced Structures</b>			180 861 212 213 214 215 1396 717 2288 479 480 1161 1162 863 864 865 2016 1397 1569 860 1571 1572 1573 1164 1395 1817 2159 1160 1782 1783 1784 1785 1857 2489 1570 2072 2283 1835 2307
<b>Riemann Method</b>			1820 2232 1985 2160 1995
	2103		
<b>Relaxation Method (Mathematics)</b>		<b>Ribs (Supports)</b>	
	1119	2142	979
<b>Reliability</b>		<b>Ride Dynamics</b>	
	1144	2350 2351	903 2684 2685 1846 1847 1849 2686 2359
<b>Remote Control</b>		<b>Rigid Frames</b>	
	1548 1549	1913	
<b>Resonance Pass Through</b>		<b>Rigid Inclusion-Containing Media</b>	
491	1807 2518 409		78
<b>Resonance Tests</b>		<b>Rigid Rotors</b>	
	1105	1077	487 1638 69 2517
<b>Resonant Bar Technique</b>		<b>Ring Springs</b>	
use Resonance Bar Technique			594
<b>Resonant Cavities</b>		<b>Rings</b>	
use Cavity Resonators		1940 1041 652 593 2164 1015 1276 1151 1685 1926 2411 2595	
<b>Resonant Frequencies</b>		<b>Ritz Method</b>	
411 1483 1234	1626	1368 1799	2361
2091	2526	2539	2138 2158
<b>Resonant Response</b>		<b>Ritz-Galerkin Method</b>	
2370 1331 1272 1503 1024 425 1336		962	964 1245
2203			
2453		<b>Road Roughness</b>	
<b>Resonators</b>		902	275
	193	1529	
	1513		
<b>Response Spectra</b>		<b>Road Tests (Ride Dynamics)</b>	
822 1283 1384 2195 416	1149	use Ride Dynamics	
1712	2215	2199	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Roads (Pavements)</b>		<b>Rotating Structures</b>
	886	190 221 502 213 94 675 186 67 8 669
<b>Rock Drills</b>		1950 301 2512 513 174 695 676 677 218 779
	1819	2270 411 2143 224 1685 846 697 448 1749
		1091 2203 494 876 2347 698
		2361 504 1116 2348
<b>Rocket Motors</b>		2511 514
1042	1467	1644
		2124
<b>Rocket Sleds</b>		<b>Rotational Response</b>
2090		1921 1825 667
<b>Rocks</b>		<b>Rotatory Inertia Effects</b>
2540		1040 1671 1662 983 1896 1927 1668 109
<b>Rods</b>		1680 2332 1493 2386 1937 2518 609
1050 2381 1602	2454 345 86 2597 1658	1910 2103 779
2200	2455 896	1929
<b>Roller Bearings</b>		<b>Rotor Bearing Systems</b>
1891	2036 2107 1638 1239	use Rotors
<b>Rolling Contact Bearings</b>		<b>Rotor Blades (Turbomachinery)</b>
2670 2571	2569	91 2364 1888 189
<b>Rolling Friction</b>		949
631	654	758 2099
<b>Root Mean Squares</b>		<b>Rotor Blades (Rotary Wings)</b>
1590	1953	use Rotary Wings
<b>Rotary Compressors</b>		<b>Rotor (Computer Program)</b>
2532		475
<b>Rotary Inertia Effects</b>		<b>Rotor-Induced Vibration</b>
use Rotatory Inertia Effects		732
<b>Rotary Pumps</b>		<b>Rotors</b>
	1179	220 301 2 3 4 315 486 487 488 69
		490 491 212 223 604 445 506 497 498 219
		500 501 222 493 724 495 606 507 508 489
		580 521 492 503 864 505 656 587 518 499
		700 581 522 523 874 605 716 697 588 509
		870 701 702 603 954 1115 876 867 868 589
		1170 871 722 723 1154 1175 1176 1177 1168 869
		1180 951 872 873 1394 1225 1226 1247 1228 1229
		1400 1361 1152 953 1404 1365 1366 1407 1408 1409
		1410 1401 1172 1153 1584 1405 1406 1577 1538 1809
		1540 1721 1402 1173 1724 1565 1586 1807 1578 2009
		1640 1801 1582 1743 2104 1585 1646 2047 1808 2049
		1740 2051 1652 1803 2294 2505 1806 2507 2048 2239
		2050 2101 1892 1813 2474 2515 2506 2517 2518 2509
		2280 2291 2292 1893 2514 2585 2516 2527 2528 2529
		2290 2301 2572 2513 2524 2665 2596 2667 2668 2579

(cont'd)

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1674 1575-1799 1800-2046 2047-2280 2280-2604 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Rotors (continued)</b>				<b>Scaling</b>							
2360 2511 2592 2523	2666	2669	2250	183	634	925	1737				
2510 2521 2662 2593				1604							
2530 2531 2633											
2660 2661 2663											
<b>Rotors (Machine Elements)</b>				<b>Screws</b>							
use Rotors				600							
<b>Rubber</b>				<b>Seals</b>							
use Elastomers					1582	603	604	605	336	1537	2118
					2592	2593	764	2585	606	1897	
								2594	2595	716	2117
										2106	
											2596
<b>Runway Roughness</b>											
290 1461		288	289	<b>Seat Belts</b>							
				181	1632						2327
				<b>Seismic Analysis</b>							
				1590	261	882	1283		1255		1198 1779
				1601	1502	2383		1915			
				2171	2312						
<b>Safety Belts</b>				<b>Seismic Barriers</b>							
use Seat Belts											2068
<b>Safety Restraint Systems</b>											
2330 181 1222		277		<b>Seismic Design</b>							
1632		2327		240	241	792	153	384	735	16	17 248 379
				1320	261	1422	253	794	1195	216	1167 468 479
<b>Sand</b>				2601	2192	1143	1144	1825	376	1777	1158 1399
		2466	1197	2691		2193		1835	1166	2317	1318 2309
								2195	1916		1398
<b>Sandwich Laminates</b>				<b>Seismic Detectors</b>							
use Sandwich Structures											2078
<b>Sandwich Panels</b>				<b>Seismic Excitation</b>							
use Panels and Sandwich Structures				250	821	242	1983	154	1705	416	737 1158 1279
<b>Sandwich Structures</b>				1661	892	2383	684	2135	736	2097	1498 2189
341 2602	2395	1928	2139	2621	1072	2433	1144		796		1948
2141			2219					1962	2064	2066	2098
								2062	2674		2178
<b>SAP (Computer Programs)</b>				<b>Seismic Isolation</b>							
813				60							2097 2098
<b>Satellite Antennas</b>											
use Spacecraft Antennas				<b>Seismic Response</b>							
				30	251	372	773	24	15	386	27 28 29
<b>Satellites</b>				260	771	772	783	344	25	806	257 368 239
		1128		370	891	782	793	764	545	1706	267 688 259
<b>Saws</b>				400	2311	822	883	804	795	1916	847 798 399
	2362	2055	2056	800	2531	1022	893	824	825	2136	2177 1038 799
				820		2392	1193	884	1385		1518 889
											(cont'd)

**Abstract**

Numbers: 1-217 218-483 484-719 720-906 967-1167 1168-1402 1403-1574 1575-1700 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Seismic Response (continued)</b>			<b>Shear Waves</b>													
890	1423	1424	1595	2628 1099	1270		1699									
2070	1823	2134	1785		2419											
2560	2193	2194	1825			<b>Shells</b>										
			2614			120	121	122	123	124	125	126	117	118	119	
						360	361	362	363	364	365	366	617	368	259	
						620	1011	1012	973	1014	855	426	1007	1008	359	
						1280	1041	1282	1013	1684	865	1016	1017	1498	469	
						1680	1281	1682	1673	1944	1005	1276	1677	1678	1009	
						1940	1681	1942	1683	2164	1015	1676	2167	2168	1679	
						2160	1941	2162	1943	2254	1945	2166	2407	2408	1939	
						2390	1951	2612	2163		2145	2406	2607	2608	2159	
						2410	2161		2613		2165		2618	2409		
						2610	2361								2609	
<b>Self-Excited Vibrations</b>																
490	561	1172	1063		1295	516	1327		489							
1210	1481	2102	2213		1485	1286				1329						
1710										1479						
2200										1689						
<b>Semiactive Isolation</b>																
					2564	2565										
<b>Semitrailers</b>																
							1278									
<b>Series (Mathematical)</b>																
2132																
<b>Shading Techniques</b>																
					1534											
<b>Shafts</b>																
1410	2521	1162	1403	1404	2295	486			868	1169						
1720		1802	2253	1564	2525	2296			1168	2519						
1800		2522		2524					2688	2579						
2520				2594												
<b>Shafts (Machine Elements)</b>																
720	721	512	1173	484	5	6	7	708	219							
1170	831		1543		225	1366	857	2048	669							
1580	1171				475	1576	1807									
1181					1405											
1411					1575											
1741																
<b>Shakedown Theorem</b>									1349							
<b>Shakers</b>																
					2242		1106	1197		2649						
<b>Shear Deformation Effects</b>																
use Transverse Shear Deformation Effects																
<b>Abstract</b>																
Numbers:	1-217	218-483	484-719	720-866	867-1187	1188-1402	1403-1574	1575-1799	1800-2046	2047-2280	2280-2504	2505-2691				
<b>Volume 13</b>																
<b>Issue:</b>	1	2	3	4	5	6	7	8	9	10	11	12				

<b>Shock Loads</b>		<b>Simulation</b>	
use Shock Excitation		2250 1051 1112 1833 1554 715 1356	549
		2071 1252 2674 1555	1359
		2112	
<b>Shock Measurement</b>			
use Measurement Techniques and Shock Response			
<b>Shock Response</b>		<b>Single Degree of Freedom Systems</b>	
1520 401	2196 767 478 119	1080 2561 1064 2205 2486 827 1078	
2080 2231	2456 917	1770 2004	
2301			
		<b>Size Effects</b>	
<b>Shock Response Spectra</b>			1298
1980 1142	2197 48		
<b>Shock Tests</b>		<b>Skew Plates</b>	
31 2092 1733 2244 2245	576 687 2248 2079	780	777 988
2242 2243	686 2247 2249		
	2246 2287		
<b>Shock Tube Testing</b>		<b>Skin-Stringer Method</b>	
	1519		978
		<b>Slabs</b>	
			1038 619
<b>Shock Wave Propagation</b>		<b>Sleeve Bearings</b>	
1980 1321 692 1323	1766 397 398 1979		956
1981 1322	1317 638		
	1707 1708		
	2187 1978	<b>Slider Crank Mechanism</b>	
		1654	
<b>Shock Wave Reflection</b>		<b>Slip Amplitude</b>	
	2186		579
<b>Shock Waves</b>			
1980 1981	1004	<b>Sloshing</b>	
2390	734	1274 1275	1277 1278 1279
		1674 1675	1948 1949
<b>Shrouds</b>			2348
2041		<b>Small Amplitudes</b>	
		2462	2604
<b>Shuttles (Spacecraft)</b>		<b>Snap Through Problems</b>	
	1625 1626		348
<b>Signal Processing Techniques</b>			
1540 1563	2215 186 187	<b>Soils</b>	
		1830	733
<b>Signature Analysis</b>			2466
	186		2449
	676	<b>Solar Cells</b>	
			1688
<b>Silencers</b>		<b>Solid Propellant Rocket Engines</b>	
	2563	55 1026	
		2175 2056	561 562
<b>Silos (Missile)</b>		<b>Sonic Boom</b>	
use Missile Silos		1970 1051 1392	1148

**Abstract**

Number: 1-217 218-463 484-710 720-866 867-1167 1168-1402 1403-1674 1675-1799 1800-2046 2047-2299 2290-2604 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Sonic Fatigue Resistant Structures</b>	1218	<b>Sound Waves</b>	1514 1505 1696 1037 138 1969
<b>Sound Attenuation</b>		620 381 2452	1860 1611
610   1292 633 1214		1920 2611	1695   1047 1308 2179
2422		2180	1955   1697 1448
<b>Sound Detectors</b>		2410	1698
1735		2430	1968
<b>Sound Generation</b>	2428	<b>Spacecraft</b>	2028
2620   2362		210 411 1332	294 295 296 1627 48 559
<b>Sound Insulation</b>		560 421 1402	1465 1666 2347 1568 1079
use Acoustic Insulation		1400 1401 1582	1875 1716   2088 2089
<b>Sound Level Meters</b>		2291 1672	2346   2348
1732		<b>Spacecraft Antennas</b>	
<b>Sound Measurement</b>	1309	94	
1311	2459	<b>Spacecraft Components</b>	
<b>Sound Power Levels</b>		561 562 2013	566 557 558
314 2325 2006		<b>Space Shuttles</b>	
1704		1230 561 562	564 565 566 557 508 1549
<b>Sound Pressure Levels</b>		2291 1582	1466 558
1013	1196	<b>Specifications</b>	
<b>Sound Pressures</b>	1695	1186 2287 2288 2289	
1695		2438	
<b>Sound Propagation</b>		<b>Speckle Metrology Techniques</b>	
1310 1581 1812 2173 614	136 1857	434	2647
1610 2421   2423 624	1036 2547		
1860	1506 2687	<b>Spectral Analysis</b>	
2420		use Spectrum Analysis	
<b>Sound Reflection</b>	1698	<b>Spectral Energy Distribution Techniques</b>	
630		160 681 682   194 1385 2206	1628
<b>Sound Transducers</b>		1690	
56		<b>Spectrum Analysis</b>	
2646		40 2071 2382 2233 464 675 2486 2657 448 1179	
<b>Sound Transmission</b>		2230 2231   2443 2444   2656	1138
630 621 1032 933 104 1015 106	128 349	2580   2614	1518
1960 1031 1292	634 1465 1016		1738
1971 2602	2535 1956	<b>Spectrum Analyzers</b>	
	2426	432   674	676 137 1728
<b>Sound Transmission Loss</b>		1695   427	2179
2650	613 1294 2175	2437	
		<b>Spherical Bearings</b>	
		320 761	77

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1187 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Spherical Shells</b>	<b>STAGS (Computer Program)</b>
122 123 1684 1945 366 117 1008 1009	2254
1683 1007 2408 1939	
2613	
<b>Spherical Waves</b>	<b>Stalling</b>
1700 1053	948
<b>Spindles</b>	<b>Standards</b>
813	<b>use Standards and Codes</b>
	<b>Standards and Codes</b>
	2691 1163 24 155 216 17 718 719
<b>Spring Constants</b>	794 1165 376 737
	824
955 316	1164
606	1574
	2324
<b>Spring-Mass Systems</b>	
<b>use Mass-Spring Systems</b>	<b>Statistical Analysis</b>
	1850 1871 542 913 144 2276 2497 1408 639
<b>Springs</b>	1972 2033
62 1235 2358	2643
1475	
<b>Springs (Elastic)</b>	<b>Statistical Energy Analysis</b>
1071 593 306 307	200 2677 2499
<b>Spur Gears</b>	<b>Statistical Energy Methods</b>
1241 2112 2113 2114 325 327 1168	1100 144
2372 2367	
	<b>Statistical Linearization</b>
	2497 2498
<b>Squeeze Film Bearings</b>	
2240 1237 1638	<b>Stators</b>
	2290
<b>Squeeze Film Dampers</b>	
2570 71 213 2634 75 2049 2569	<b>Steady State Excitation</b>
1523 2633	<b>use Periodic Excitation</b>
<b>Stability</b>	<b>Steady-State Response</b>
2370 2261 2 1553 1684 725 2027 2478 1579	<b>use Periodic Response</b>
2480 2371 742 1694 1395	
1652	<b>Steam Generators</b>
	<b>use Boilers</b>
<b>Stability Analysis</b>	<b>Steam Turbines</b>
<b>use Stability</b>	1641 1742
<b>Stability Methods</b>	
	<b>Steel</b>
	1150 1721 972 2373 1194 1185 236 237 238 1189
	1750 2441 1192 1704 1195 1186 597 1188
	2641 2352 2064 1525 2176 1187 2178
	2642 2094 2375 1717
	2354 2097
<b>Stabilization</b>	2374 2637
	2424
<b>Staggered Solution Schemes</b>	
2254	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Steepest Descent Method</b>		<b>1119</b>	<b>Stochastic Processes</b>			
			1550 191	844 845	227 458	2259
			2260 711	1634	957 728	
<b>Steering Effects</b>	<b>33</b>	<b>1846</b>	2310 971		868	
			2580 1461		2018	
<b>Steering Gear</b>					2228	
2651		276		<b>Stodola Method</b>		
<b>Steering Wheels</b>					<b>1663</b>	
use Steering Gear				<b>Storage</b>		
<b>Step Response</b>						<b>646</b>
1692 2034				<b>Storage Tanks</b>	782 783 784	
<b>Stick-Slip Response</b>		<b>1986</b>			1673	
<b>Stiffened Panels</b>			<b>98</b>	<b>Stress Waves</b>		<b>2445</b>
2140						
<b>Stiffened Plates</b>				<b>Stress Analysis</b>	2223 2224	<b>2689</b>
350 992 343						
780 993				<b>Stringers</b>		
990					1015	
<b>Stiffened Shells</b>				<b>Strings</b>		
1940	2164 1015 1276 2167			960		<b>608 2379</b>
<b>Stiffened Structures</b>			<b>978</b>	<b>Strips</b>		
1903 2384					1765	<b>1257</b>
<b>Stiffener Effects</b>		<b>2515</b>	<b>2167</b>	<b>Strouhal Number</b>		
			<b>2527</b>		1764	
<b>Stiffness</b>				<b>Structural Components</b>		
2600	1584 235			use Structural Members		
	2295					
<b>Stiffness Coefficients</b>				<b>Structural Elements</b>		
560 1641 1582 313 884 725 586		308 319		use Structural Members		
590 1651 1642 603 2204 885 656		518 929				
820 2291 2582 1133	2585 956	1758 1129		<b>Structural Members</b>		
1910 2571	1683	1386	1828 1239	1870 1081 1692 533 834 625 1296 667 1298 1039		
2110	2513	1956	1809	1691 1163 1004 2425 2176 1157 2048		
	2523	2376		1964 2426 1297 2178		
	2583			1737		
				2177		
<b>Stiffness Methods</b>				<b>Structural Modification Effects</b>		
2031	1136 1127 1928			2651 2552		<b>2367 2369</b>

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

Volume 13

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Structural Response</b>		<b>Supports</b>	
2630 641 642	1984 805	2120 251 1502 843 1384 1475 501 2515	379 499
<b>Structural Synthesis</b>		721	
1141	1125 1556 1757	791	
<b>Structure-Borne Noise</b>		<b>Surface Intensity Technique</b>	
2353	2555	1542	
<b>Structures</b>		<b>Surface Roughness</b>	
		1430 1431 2090	276 328 329
<b>Struts</b>		<b>Surges</b>	
	2424	515	
<b>Subharmonic Oscillations</b>		<b>Surveys</b>	
	1407	use Reviews	
<b>Submarine Hulls</b>		<b>Suspended Structures</b>	
2163	2247 2248 2079	963 84 2385	2119
<b>Submarines</b>		<b>Suspension Bridges</b>	
552	2255	730 11 1191	
<b>Submerged Structures</b>		<b>Suspension Systems (Vehicles)</b>	
2380 2611 2613 344 1715 1006 2317 364 2256 2254	1669	61 182 903 1434 305 2356 57 2564 2565 577	59
<b>Substructure Coupling</b>		<b>Symposia</b>	
use Component Mode Synthesis		use Proceedings	
<b>Substructuring Methods</b>		<b>Synchronous Motors</b>	
1190 2501 732 1554 1125 1426 1597 2274 1757	2299 2409	496	
<b>Subynchronous Vibration</b>		<b>Synchronous Vibration</b>	
1644		1710 1693	1409
<b>Subway Cars</b>		<b>System Identification Techniques</b>	
2331		850 851 463 464 1775 1300 2501 2034 2500	1777 888 849 2678 859 1139 1299
<b>Successive Approximation Method</b>			2059
360			2679
<b>Sum and Difference Frequencies</b>		<b>Systems Approach</b>	
2655 2656			1238
<b>Supersonic Aircraft</b>			
1453			

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2288 2289-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

	- T -	
<b>Tanks (Containers)</b>		<b>Testing Instrumentation use Test Equipment and Instrumentation</b>
1950 1951	1673 1274 1275	1277 248 1279
	1674	1278 1949
		1948
		2348
<b>Taxing Effects</b>		1340 1271
		2240 2011
	947	1574 1105 2246 1087 1298 719
<b>Taylor Series</b>		2374 1165 2466 1357 1618 889
	2422	2464 2245
		1887 2328 1199
		2237 1209
		2287 1339
		2289
<b>Temperature Effects (Excitation)</b>		<b>Textile Looms</b>
use Thermal Excitation		1184 235
<b>Test Data</b>		<b>Textile Spindles use Spindles</b>
use Experimental Data		
<b>Test Equipment and Instrumentation</b>		<b>Thermal Conductivity</b>
2010	1733 437 205 1106 1537 548 1209	1122
	2235	2107 1358
	2465	2287 1538
<b>Test Facilities</b>		<b>Thermal Effects</b>
690 691 182 233 484 2015 1786	477 438 2649	1188
692 693 694	2467 658	
2653 2014	2587 838	
2234	2238	
2654	2468	
<b>Text Fixtures</b>		<b>Thermal Excitation</b>
use Test Facilities		1280 1902 2603
		1942
<b>Test Instrumentation</b>		1235 1266 67 1178 1689
use Test Equipment and Instrumentation		2405 2029
<b>Test Models</b>		<b>Thermal Insulation</b>
	183	2549
<b>Test Specifications</b>		<b>Thermelasticity</b>
	2289	2200
<b>Test Stands</b>		1897 1978
	2585	
<b>Testing Apparatus</b>		<b>Thermoviscoelasticity Theory</b>
use Test Equipment and Instrumentation		167
<b>Testing Equipment</b>		<b>Thickness Effects use Geometric Effects</b>
use Test Equipment and Instrumentation		
<b>Abstract</b>		<b>Three Dimensional Problems</b>
Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1874 1675-1799 1800-2046 2047-2200 2200-2604 2605-2691	2282	
<b>Volume 13</b>		<b>Thrust Bearings</b>
<b>Issue:</b>	1 2 3 4 5 6 7 8 9 10 11 12	70 1642 583
		590
		2110
		<b>Tilting Pad Bearings</b>
		1642
		315

<b>Time-Dependent Excitation</b>	<b>Towed Bodies</b>
1913 94	126 137
	<b>use Towed Systems</b>
<b>Time-Dependent Parameters</b>	<b>Towed Systems</b>
431 1292	907 2608
1771	1490
	<b>Towers</b>
	240 1593 534
1190 201 192 1733 1954 675 826 847 1228 679	1190 1803 1824
1420 931 1102 2485 2486 1847 1609	248 249
1101 1752 2279	2538 1999
1351	
1731	1436 59
	<b>Track Roughness</b>
<b>Timoshenko Theory</b>	<b>Tracked Vehicles</b>
1410 91 92 983 625 767 768 1659	747
2600 2382 2115 1248 1899	
	<b>Traction Drives</b>
	2303 2304
<b>Tire Characteristics</b>	
1205 1887	
1845	
	<b>Tractors</b>
	743 744 745
<b>Tires</b>	577 578
63 946 1887 308 309	1208
1476 2359	
	<b>Traffic Induced Vibrations</b>
	12 385
<b>Toroidal Shells</b>	
2166	
	<b>Traffic Noise</b>
	150 811 52 13 634
<b>Torque</b>	1206 807 808 149
2457	810 911 912 913 1844
	907 908 809
	910 1352 1233 1974
	1207 909
<b>Torsion Bars</b>	1882 2073
62	1877
	2622
<b>Torsional Excitation</b>	<b>Traffic Sign Structures</b>
352 2396 2607 1169	1314 1516
	900 901
	1589
	<b>Trailers</b>
	742 743 744 745 906
<b>Torsional Response</b>	904 905 2356
1821 333 1205 857 1889	1605
2101 1253 1705 1477 2189	
	<b>Trains</b>
	<b>use Railroad Trains</b>
<b>Torsional Vibration</b>	
720 521 652 93 324 225 86 527 1168 339	
950 651 1082 1663 1664 625 666 1247 2298	
1720 1171 1162 1903 1814 1655 876 1417 2588	
1800 1532 2103 1964 1815 1816	
2510 2054 2525	
2384	2473
2494	
	<b>Transducers</b>
	2360 671 672 673
	1726 1097 1098
	2012 1723
	<b>Transfer Functions</b>
	1071 382 383 1124
	2086 1627 948

**Abstract**

Numbers: 1-217 218-483 484-719 720-868 867-1187 1168-1402 1403-1574 1575-1799 1800-2046 2047-2280 2290-2504 2505-2601

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Transfer Matrix Method</b>							<b>Transverse Shear Deformation Effects</b>					
2490 1261 92	114		2676 337 98	1419			1040 1671 1662	983	1935 2386	1927	998	109
2510 1822	994		2417 968				1680	2332 1493			1668	779
			2048					2103			2518	1929
<b>Transformation Techniques</b>							<b>Transverse Vibration</b>					
	2484						1923					
<b>Transient Excitation</b>							<b>Trees (Plants)</b>					
2391 723	2125		1017 2198	1009				1974				
			1087									
<b>Transient Response</b>							<b>Trucks</b>					
2080 531 362 663	204 1265	436	117 2188	959			2350 61 1232	1433	1844 1605	1606	1097	1098
2600 2271 472 1123	354		1146 1007	2258 2299			741 2552 2553	1854 1845				
2611 2292 1833	474		1236 1267	2298 2409				2074 2325				
	2023 1024			1527	2599			2324				
	2033 1134			2167								
	1724						<b>Trusses</b>					
	1954							976				
	2414											
<b>Translational Inertia Effects</b>							<b>Tube Arrays</b>					
	1896			1009				2413	2415	2617		
<b>Translational Response</b>												
840 1921	1825	667 2588					<b>Tubes</b>					
		1477					130 131 132	133 134		96 377	378	129
							1020	2412 373	374	346 1797	638	1019
							2170	403 1234		1496	1288	1289
							2610			1796	1798	1799
<b>Transmissibility</b>												2169
use Transmissivity												
<b>Transmission Lines</b>							<b>Tuned Dampers</b>					
2120 961 962 2213	534 1245	1656					300 2561			2217	658	
1161							830					
<b>Transmission Matrix Methods</b>							<b>Tuned Frequencies</b>					
	1577						720					
<b>Transmission Systems</b>							950					
2302								<b>Tuning</b>				
								2575 2566	1227			
<b>Transportation Effects</b>												
571	635 2076	567					<b>Tunnels</b>					
2241		2077					2540		804			
<b>Transportation Noise</b>												
	149						<b>Turbine Blades</b>					
							2100 312 2363			66	1478	579
												759
<b>Transportation Systems</b>												2029
use Transportation or Transportation Vehicles												
<b>Transportation Vehicles</b>							<b>Turbine Components</b>					
	2077						1721 1992			504	1806	
												604

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2280-2504 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Turbine Engines</b>			<b>Unbalanced Mass Response</b>											
1810	222		1180	1411	722	493	1804	5	76	2517	1408	509		
		865	2050		732						2518	1409		
		1745	2660									1739		
<b>Turbines</b>														
1810	2581	1742		1888										
	2052													2208
<b>Turbocompressors</b>														
		2596												
<b>Turbofan Engines</b>														
1291			2297											
1451														
<b>Turbofans</b>														
1580		1413												
<b>Turbogenerators</b>														
1740	2513		2506	2507										
	2573													
<b>Turbomachinery</b>														
220	511	72	653	1394	485	596	707	508	39					
1740	1641	512	1893	2634	2505	1806	1117	2508	489					
2280	2051	702				1996	1367		1579					
		732				2566			2539					
		2532												
<b>Turbomachinery Blades</b>														
2361	952	313		485										
		2103												
<b>Turbomachinery Noise</b>														
		1174												
<b>Turbulence</b>														
131		933	614		2416	2047								
391			774											
2051			1944											
<b>Turbulent Friction</b>														
		1763												
<b>Two-Degree of Freedom Systems</b>														
		963		1556	1387									

- U -

<b>Ultrasonic Tests</b>		<b>USA (Computer Program)</b>												
use Testing Techniques			2254											

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2505-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12		
--------	---	---	---	---	---	---	---	---	---	----	----	----	--	--

- V -										Vibrating Foundations								
										535				967				
<b>Valves</b>										<b>Vibrating Structures</b>								
81	82	763		1485	1026	737	1488	369		960	1271		1924	145	1056	977		
781	602				1486	1487				1920	2201		2204	1565	1776	2207		
1051					1896	1497				2020			2454	1755		1925		
2591					2116									2025				
<b>Van Der Pol Oscillators</b>										<b>Vibration Absorbers</b>								
										use Vibration Absorption (Equipment)								
<b>Vanes</b>										<b>Vibration Absorption (Equipment)</b>								
1										300	1881	572		214	1335		658	
2201																		
<b>Vans</b>										<b>Vibration Absorption (Materials)</b>								
										302								
<b>Variable Amplitude Excitation</b>										<b>Vibration Analysis</b>								
										1930	1011	952	1243	1354	615	2436	1157	
										2231	1122	2463	2164	865	2596	2017	2568	
										2351	1592			1415		2647	1789	
											2322			2395			2499	
														2595			2549	
																	2649	
<b>Variable Cross Section</b>										<b>Vibration Analyzers</b>								
1800	1261	92	1933	2294		1506	337	968		1532		434		526		1728		
1910		1262	2143				777	1178										
		1922	2173				2417	1268										
		1932	2423					1588										
		2122																
		2152																
		2332																
<b>Variable Material Properties</b>										<b>Vibration Control</b>								
2480	2161	1852	1173		2295	876	777		1809	1780	521	212	3	284	55	146	497	
									2029	2310	1061	332	553	1644	295	1116	517	
										1141	1452	1183	1874	495	1336	1607	1738	
										1161		2513	2624	915	1386	1987	2288	
										2651				1145	1396		2588	
														1855	1686			
														1786				
														2126				
<b>Variance Analysis</b>										<b>Vibration Dampers</b>								
										651	652			2214				
<b>Variational Methods</b>										<b>Vibration Damping</b>								
1302										70	161	302		2624	75	146	307	
										480	231	972		1335	496	977	1538	
														626	1337			
														2216	2217			
														2307				
<b>Velocity</b>										<b>Vibration Detectors</b>								
										2461		173						
<b>Velocity Measurement</b>																		
1092																		
<b>Ventilation</b>																		

## Abstract

Numbers: 1-217 218-483 484-719 720-886 887-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2604 2605-2801

## Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

<b>Vibration Effects</b>			<b>Vibration Response Spectra</b>	
1020	53	537		2586
<b>Vibration Excitation</b>			<b>Vibration Signatures</b>	
570	873	568 2349		704
1290		1878		
1570		2428	<b>Vibration Source Identification</b>	
<b>Vibration Frequencies</b>				2505 2526
53			<b>Vibration Spectra</b>	
1933			use Vibration Response Spectra	
<b>Vibration Generation</b>			<b>Vibration Testing</b>	
1851		439		1157
<b>Vibration Isolation</b>			<b>Vibration Tests</b>	
1621	1634 1635	146 657	690 681 682 683	134 215 426 1677 308 439
	2624	306 2307	1230 691 1012	384 685 566 2237 2238 1019
<b>Vibration Isolators</b>			1101 2412	1835 1106 2467
213 214	56	1638 2209	1811	2015 2236
2353	2096		2241	2235
<b>Vibration Measurement</b>			<b>Vibration Tolerance</b>	
1100 561 2232 1273	174 175 176 177	478 129	861 802	
1781 2462 1593	674 745 936 1727	718 669	1232	
2281 2233	1175	1997		
		2017	1099	
			1649	
			1729	
<b>Vibration Monitoring</b>			<b>Vibration Transducers</b>	
	446	698		2456
<b>Vibration Prediction</b>			<b>Vibrators (Machinery)</b>	
112			2061	1358
212				
<b>Vibration Probes</b>			<b>Vibratory Conveyors</b>	
1353 174	176		use Vibrators (Machinery) and Materials Handling Equipment	
	446			
<b>Vibration Reduction</b>			<b>Vibratory Techniques</b>	
use Vibration Control			2052 2544	696 1107 1819
				2289
<b>Vibration Resonance</b>			<b>Vibratory Tools</b>	
use Natural Frequencies			583 2544	1419
<b>Vibration Response</b>			<b>Vincent Circle Method</b>	
220 2521 522 523 554 1235 506 297 1788 429				1386
430 762 1713 614 1485 556 1297 2088 649			Violins	
1350 1722 744 1685 1296 1787	1159			2648
1570 2022 1714 1795 1326 2527	1389		Viscoelastic Core-Containing Media	
2142	1949		2141 2602 1493 2204	

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1675-1799 1800-2046 2047-2289 2290-2504 2506-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Viscoelastic Damping</b>					<b>Vulnerability</b>			
630	1064	1396		2219				2246
1150								
1990								
<b>Viscoelastic Materials</b>							<b>- W -</b>	
		1396						
<b>Viscoelastic Media</b>					<b>Walls</b>			
2180	412	414	427	1319	1962	1323	384	1255
	662			2029	1963			246
<b>Viscoelastic Properties</b>								806
2610	2151	2212	663	104	1266	357	58	2449
				944	2126	2597	338	
				1984			1528	
<b>Viscoelasticity Theory</b>					<b>Warheads</b>			
		2226						2198
<b>Viscoplastic Media</b>					<b>Warships</b>			
		166					704	
<b>Viscosity</b>					<b>Waste Treatment</b>			
		1945						629
<b>Viscosity Effects</b>					<b>Water Hammer</b>			
	2613							717
<b>Viscous Damping</b>					<b>Water Waves</b>			
300	1911	2192	423	655	280	271	1532	863
			2512	2276	1840	1841	2072	1254
				1077	2314	2335		925
				2518	2211	2202		
				419				547
				1945				278
				2209				739
				2095				897
<b>Visual Performance</b>					<b>Waterworks</b>			
		53					804	
<b>Vortex-Induced Excitation</b>					<b>Wave Absorption</b>			
		1327						2446
<b>Vortex-Induced Vibration</b>					<b>Wave Analyzers</b>			
	972	2434	85	1176	127	2388	2389	2645
<b>Vortex Noise</b>					<b>Wave Diffraction</b>			
1500					1701	1383	1304	1045
					2181	2443	2444	1046
						1256	1827	1308
						1967	1508	1899
<b>Vortex Shedding</b>					<b>Wave Equation</b>			
1500	131	132	1953	894	1908	2389	1552	
1790	141	1792						
	881							
	1791				<b>Wave Number</b>			
					<b>use Frequency</b>			

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 867-1167 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2605-2691

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

<b>Wave Propagation</b>			<b>Wheels</b>									
400 171 412 413 414 255 1766 167 638 389			2441 1992		64	65		1097	1098	2099		
970 2421 1302 713 1044 1055 2026 1037 1068 1969					2664							
1350 2451 1552 733	1305 2626 1767											
1700 2442 1043	1695 2447		<b>Wheelsets</b>									
2180 2452 1053	1955 2597							945	1436			
2430	1983 1965 2687							1355				
2450	2225		<b>Whipping Phenomena</b>									
	2445		2163									
<b>Wave Reflection</b>			<b>Whirling</b>									
	1303	2446	1411 2592 1893		485	2516	2557	2578	489			
	1563		2363		2295	2587			519			
									589			
<b>Wave Refraction</b>		2446								2169		
<b>Wave Scattering</b>			<b>Wind-Induced Excitation</b>									
1300 1301 1562			730 291 292 293 284 805 36					1158	729			
			1200 881 1152 1153 874 2425 416					1388	949			
			1640 1191 1822 1593 1824 1226					2538	1389			
<b>Wave Transmission</b>			1441 1993 1944 1656						1429			
2162 1303		848	1871 2063 1964 1866						1589			
					2536				1999			
<b>Waveguide Analysis</b>			<b>Wind Mills</b>									
	1055	1767 1988	1803									
<b>Waveguides</b>			<b>Wind Tunnel Test Data</b>									
1701 1272									1458			
<b>Weapons Effects</b>			<b>Wind Tunnel Testing</b>									
862		2087	1824 1585						1458			
<b>Weapons Systems</b>			<b>Wind Tunnel Tests</b>									
	2094	2246	1090 881 143 754 1175 1176 1217						729			
<b>Wear</b>			1620 1253 1054									
320	172 133 2074				1584							
	1482		<b>Wind Tunnels</b>									
<b>Wedges</b>			2654									
		1926	<b>Wind Turbines</b>									
			312						227 1578			
<b>Welded Joints</b>			872						1888			
	184 2155	188										
	2374 2375	258	1412									
<b>Welding</b>			<b>Windmills</b>									
		986	1640 1583							949		
<b>Wheel Shimmy</b>			<b>Wing Stores</b>									
	946 947		1220 1621 1622 1623 554 2345						1137 938 1459			
			1460						1457 1458 1869			
					2357							

**Abstract**

Numbers: 1-217 218-483 484-719 720-866 887-1187 1168-1402 1403-1574 1575-1799 1800-2046 2047-2289 2290-2504 2606-2601

**Volume 13**

Issue:	1	2	3	4	5	6	7	8	9	10	11	12
--------	---	---	---	---	---	---	---	---	---	----	----	----

Wire  
1490

Work and Energy Balance  
2514

Wood  
943

Abstract

Numbers: 1-217 218-483 484-719 720-888 887-1167 1168-1402 1403-1574 1575-1799 1800-2048 2047-2289 2290-2504 2505-2601

Volume 13

Issue: 1 2 3 4 5 6 7 8 9 10 11 12

# TECHNICAL NOTES

A. Leissa and Y. Narita

**Vibrations of Free Circular Plates Having Elastic Constraints and Added Mass Distributed along Edge Segments**

J. Appl. Mechanics, Trans. ASME, 48 (1), pp 196-198 (Mar 1981) 3 figs, 6 refs

M.A.M. Torkamani

**Method of Direct Solution to Inverse Problems**

ASCE J. Engrg. Mechanics Div., 107 (2), pp 424-429 (Apr 1981) 2 figs, 6 refs

P.R. Brazier-Smith, D. Butler, and J.R. Halstead

**The Determination of Propagation Path Lengths of Dispersive Flexural Waves through Structures**

J. Sound Vib., 75 (3), pp 453-457 (Apr 8, 1981) 4 figs, 4 refs

S.M. Correa, D.L. Sengupta, and W.J. Anderson

**Inflight Aircraft Vibration Modes and Their Effect on Aircraft Radar Cross Section**

J. Aircraft, 18 (4), pp 318-319 (Apr 22, 1981) 4 figs, 6 refs

J.R. Kuttler and V.G. Sigillito

**On Curve Veering**

J. Sound Vib., 75 (4), pp 585-588 (Apr 22, 1981) 2 figs, 2 tables, 4 refs

C.T. Leung, N.W.M. Ko, and K.H. Ma

**Heat Transfer from a Vibrating Cylinder**

J. Sound Vib., 75 (4), pp 581-582 (Apr 22, 1981) 1 fig, 4 refs

S.V. Kulkarni and K.B. Subrahmanyam

**Reissner Method Calculations of Natural Frequencies of Torsional Vibrations of Tapered Cantilever Beams**

J. Sound Vib., 75 (4), pp 589-592 (Apr 22, 1981) 2 tables

T. Irie, G. Yamada, and M. Tsujino

**Natural Frequencies of Concavely Shaped Polygonal Plates with Simply Supported Edges**

J. Acoust. Soc. Amer., 69 (5), pp 1507-1509 (May 1981) 2 figs, 1 table, 10 refs

R.E. Mickens

**A Uniformly Valid Asymptotic Solution for  $d^2y/dt^2 + y = a + ey^2$**

J. Sound Vib., 76 (1), pp 150-152 (May 8, 1981) 8 refs

J.S. Bandat

**Spectral Bandwidth, Correlation Duration, and Uncertainty Relation**

J. Sound Vib., 76 (1), pp 146-149 (May 8, 1981) 2 refs

## PERIODICALS SCANNED

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
<b>ACTA MECHANICA</b> Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Acta Mech.	<b>JOURNAL OF ENGINEERING FOR POWER</b>	J. Engng. Power, Trans. ASME
<b>ACUSTICA</b> S. Hirzel Verlag, Postfach 347 D-700 Stuttgart 1 W. Germany	Acustica	<b>JOURNAL OF ENGINEERING RESOURCES TECHNOLOGY</b>	J. Engng. Resources Tech., Trans. ASME
<b>AERONAUTICAL JOURNAL</b> Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. J.	<b>JOURNAL OF LUBRICATION TECHNOLOGY</b>	J. Lubric. Tech., Trans. ASME
<b>AERONAUTICAL QUARTERLY</b> Royal Aeronautical Society 4 Hamilton Place London W1V 0BQ, UK	Aeronaut. Quart.	<b>JOURNAL OF MECHANICAL DESIGN</b>	J. Mech. Des., Trans. ASME
<b>AIAA JOURNAL</b> American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	AIAA J.	<b>JOURNAL OF PRESSURE VESSEL TECHNOLOGY</b>	J. Pressure Vessel Tech., Trans. ASME
<b>AMERICAN SOCIETY OF CIVIL ENGINEERS, PROCEEDINGS</b> <b>ASCE</b> United Engineering Center 345 East 47th St. New York, NY 10017		<b>APPLIED ACOUSTICS</b> Applied Science Publishers, Ltd. Ripple Road, Barking Essex, UK	Appl. Acoust.
<b>JOURNAL OF ENGINEERING MECHANICS DIVISION</b>	ASCE J. Engng. Mechanics Div.	<b>ARCHIVES OF MECHANICS</b> (ARCHIWUM MECHANIKI STOSOWANEJ) Export and Import Enterprise Ruch UL, Wronia 23, Warsaw, Poland	Arch. Mechanics
<b>JOURNAL OF STRUCTURAL DIVISION</b>	ASCE J. Struc. Div.	<b>ASTRONAUTICS AND AERONAUTICS</b> AIAA EDP 1290 Avenue of the Americas New York, NY 10019	Astronaut. & Aeronaut.
<b>AMERICAN SOCIETY OF LUBRICATING ENGINEERS, TRANSACTIONS</b> Academic Press 111 Fifth Ave. New York, NY 10019	ASLE, Trans.	<b>AUTOMOBILTECHNISCHE ZEITSCHRIFT</b> Franch'che Verlagshandlung Abteilung Technik 7000 Stuttgart 1 Pfizerstrasse 5-7 W. Germany	Automobiltech. Z.
<b>AMERICAN SOCIETY OF MECHANICAL ENGINEERS, TRANSACTIONS</b> <b>ASME</b> United Engineering Center 345 East 47th St. New York, NY 10017		<b>AUTOMOTIVE ENGINEER (SAE)</b> Society of Automotive Engineers, Inc. 400 Commonwealth Drive Warrendale, PA 15096	Auto. Engr. (SAE)
<b>JOURNAL OF APPLIED MECHANICS</b>	J. Appl. Mechanics, Trans. ASME	<b>AUTOMOTIVE ENGINEER (UK)</b> P.O. Box 24, Northgate Ave. Bury St., Edmunds Suffolk IP21 GBW, UK	Auto. Engr. (UK)
<b>JOURNAL OF DYNAMIC SYSTEMS, MEASUREMENT AND CONTROL</b>	J. Dyn. Syst., Meas. and Control, Trans. ASME	<b>BALL BEARING JOURNAL (English Edition)</b> Bell SKF (U.K.) Ltd. Luton, Bedfordshire LU3 1JF, UK	Bearing J.
<b>JOURNAL OF ENGINEERING FOR INDUSTRY</b>	J. Engng. Indus., Trans. ASME	<b>BROWN BOVERI REVIEW</b> Brown Boveri and Co., Ltd. CH-5401, Baden, Switzerland	Brown Boveri Rev.
		<b>BULLETIN DE L'ACADEMIE POLONAISE DES SCIENCES, SERIES DES SCIENCES TECHNIQUES</b> Ans Polona-Ruch 7 Krakowskie Przedmiescie, Poland	Bull. Acad. Polon. Sci., Ser. Sci. Tech.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
BULLETIN OF JAPAN SOCIETY OF MECHANICAL ENGINEERS Japan Society of Mechanical Engineers Sanjin Hokusei Bldg. H-9 Yoyogi 2-chome Shibuya-ku Tokyo 151, Japan	Bull. JSME	HEATING/PIPING/AIR CONDITIONING Circulation Dept. 614 Superior Ave. West Cleveland, OH 44113	Heating/ Piping/ Air Cond.
BULLETIN OF SEISMOLOGICAL SOCIETY OF AMERICA Bruce A. Bolt Box 826 Berkeley, CA 94705	Bull. Seismol. Soc. Amer.	HYDRAULICS AND PNEUMATICS Penton/IPC, Inc. 614 Superior Ave. West Cleveland, OH 44113	Hydraulics & Pneumatics
CIVIL ENGINEERING (NEW YORK) ASCE United Engineering Center 345 E. 47th St. New York, NY 10017	Civ. Engrg. (N.Y.)	HYDROCARBON PROCESSING Gulf Publishing Co. Box 2608 Houston, TX 77001	Hydrocarbon Processing
CLOSED LOOP MTS Systems Corp. P.O. Box 24012 Minneapolis, MN 55474	Closed Loop	IBM JOURNAL OF RESEARCH AND DEVELOPMENT International Business Machines Corp. Armonk, NY 10504	IBM J. Res. Dev.
COMPUTERS AND STRUCTURES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Computers Struc.	INDUSTRIAL RESEARCH Dun-Donnelley Publishing Corp. 222 S. Riverside Plaza Chicago, IL 60606	Indus. Res.
DESIGN ENGINEERING Berkshire Common Pittsfield, MA 02101	Des. Engrg.	INGENIEUR-ARCHIV Springer-Verlag New York, Inc. 175 Fifth Ave. New York, NY 10010	Ing. Arch.
DESIGN NEWS Cahners Publishing Co., Inc. 221 Columbus Ave. Boston, MA 02116	Des. News	INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS IEEE United Engineering Center 345 East 47th St. New York, NY 10017	IEEE
DIESEL AND GAS TURBINE PROGRESS Diesel Engines, Inc. P.O. Box 7406 Milwaukee, WI 53213	Diesel Gas Turbine Prog.	INSTITUTION OF MECHANICAL ENGINEERS, (LONDON), PROCEEDINGS Institution of Mechanical Engineers 1 Birdcage Walk, Westminster, London SW1, UK	IMechE Proc.
ENGINEERING MATERIALS AND DESIGN IPC Industrial Press Ltd. 33-40 Bowling Green Lane London EC1R, UK	Engrg. Mtl. Des.	INSTRUMENT SOCIETY OF AMERICA, TRANSACTIONS Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222	ISA Trans.
ENGINEERING STRUCTURES IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Engrg. Struc.	INSTRUMENTATION TECHNOLOGY Instrument Society of America 67 Alexander Drive P.O. Box 12277 Research Triangle Park, NC 27709	InTech.
EXPERIMENTAL MECHANICS Society for Experimental Stress Analysis 21 Bridge Sq., P.O. Box 277 Westport, CT 06880	Exptl. Mechanics	INTERNATIONAL JOURNAL OF CONTROL Taylor and Francis Ltd. 10-14 Macklin St. London WC2B 5NF, UK	Intl. J. Control
FEINWERK U. MESSTECHNIK Carl Hauser GmbH & Co. D-800 Munchen 86 Postfach 860420 Fed. Rep. Germany	Feinwerk u. Messtechnik	INTERNATIONAL JOURNAL OF EARTHQUAKE ENGINEERING AND STRUCTURAL DYNAMICS John Wiley and Sons, Ltd. 650 Third Ave. New York, NY 10016	Intl. J. Earthquake Engrg. Struc. Dynam.
FORSCHUNG IM INGENIEURWESEN Verein Deutscher Ingenieur, GmbH Postfach 1139 Graf-Recke Str. 84 4 Dusseldorf 1 W. Germany	Forsch. In- genieurwesen	INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Engrg. Sci.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
<b>INTERNATIONAL JOURNAL OF FATIGUE</b> IPI Science and Technology Press Ltd. P.O. Box 63, Westbury House, Bury Street Guildford, Surrey, England GU2 5BH	Intl. J. Fatigue	<b>JOURNAL OF ENGINEERING MATHEMATICS</b> Academic Press 198 Ash Street Reading, MA 01867	J. Engrg. Math.
<b>INTERNATIONAL JOURNAL OF MACHINE TOOL DESIGN AND RESEARCH</b> Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mach. Tool Des. Res.	<b>JOURNAL OF ENVIRONMENTAL SCIENCES</b> Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	J. Environ. Sci.
<b>INTERNATIONAL JOURNAL OF MECHANICAL SCIENCES</b> Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Mech. Sci.	<b>JOURNAL OF FLUID MECHANICS</b> Cambridge University Press 32 East 57th St. New York, NY 10022	J. Fluid Mechanics
<b>INTERNATIONAL JOURNAL OF NONLINEAR MECHANICS</b> Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Nonlin. Mechanics	<b>JOURNAL OF THE FRANKLIN INSTITUTE</b> Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Franklin Inst.
<b>INTERNATIONAL JOURNAL FOR NUMERICAL METHODS IN ENGINEERING</b> John Wiley and Sons, Ltd. 605 Third Ave. New York, NY 10016	Intl. J. Numer. Methods Engrg.	<b>JOURNAL OF HYDRONAUTICS</b> American Institute of Aeronautics and Astronautics 1280 Avenue of the Americas New York, NY 10019	J. Hydro- nautics
<b>INTERNATIONAL JOURNAL FOR NUMERICAL AND ANALYTICAL METHODS IN GEOMECHANICS</b> John Wiley and Sons, Ltd. Baffins Lane Chichester, Sussex, UK	Intl. J. Numer. Anal. Methods Geomech.	<b>JOURNAL OF THE INSTITUTE OF ENGINEERS, AUSTRALIA</b> Science House, 157 Gloucester Sydney, Australia 2000	J. Inst. Engr., Austral.
<b>INTERNATIONAL JOURNAL OF SOLIDS AND STRUCTURES</b> Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Intl. J. Solids Struc.	<b>JOURNAL DE MECANIQUE</b> Gauthier-Villars C.D.R. - Centrale des Revues B.P. No. 119, 93104 Montreuil Cedex-France	J. de mechanique
<b>INTERNATIONAL JOURNAL OF VEHICLE DESIGN</b> The International Assoc. of Vehicle Design The Open University, Walton Hall Milton Keynes MK7 6AA, UK	Intl. J. Vehicle Des.	<b>JOURNAL OF MECHANICAL ENGINEERING SCIENCE</b> Institution of Mechanical Engineers 1 Birdcage Walk, Westminster London SW1 H9, UK	J. Mech. Engrg. Sci.
<b>ISRAEL JOURNAL OF TECHNOLOGY</b> Weizmann Science Press of Israel Box 801 Jerusalem, Israel	Israel J. Tech.	<b>JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS</b> Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	J. Mechanics Phys. Solids
<b>JOURNAL OF THE ACOUSTICAL SOCIETY OF AMERICA</b> American Institute of Physics 335 E. 45th St. New York, NY 10010	J. Acoust. Soc. Amer.	<b>JOURNAL OF PETROLEUM TECHNOLOGY</b> Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206	J. Pet. Tech.
<b>JOURNAL OF AIRCRAFT</b> American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Aircraft	<b>JOURNAL OF PHYSICS: E SCIENTIFIC INSTRUMENTS</b> American Institute of Physics 335 East 45th St. New York, NY 10017	J. Phys. E: Sci. Instrum.
<b>JOURNAL OF THE AMERICAN HELICOPTER SOCIETY</b> American Helicopter Society, Inc. 30 East 42nd St. New York, NY 10017	J. Amer. Helicopter Soc.	<b>JOURNAL OF SHIP RESEARCH</b> Society of Naval Architects and Marine Engineers 20th and Northhampton Sts. Easton, PA 18042	J. Ship Res.
		<b>JOURNAL OF SOUND AND VIBRATION</b> Academic Press 111 Fifth Ave. New York, NY 10019	J. Sound Vib.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
JOURNAL OF SPACECRAFT AND ROCKETS American Institute of Aeronautics and Astronautics 1290 Avenue of the Americas New York, NY 10019	J. Spacecraft Rockets	NOISE AND VIBRATION CONTROL Trade and Technical Press Ltd. Crown House, Morden Surrey SM4 5EW, UK	Noise Vib. Control
JOURNAL OF TESTING AND EVALUATION (ASTM) American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	J. Test Eval. (ASTM)	NOISE CONTROL ENGINEERING P.O. Box 3208, Arlington Branch Poughkeepsie, NY 12603	Noise Control Engrg.
KONSTRUKTION Spring Verlag 3133 Connecticut Ave., N.W. Suite 712 Washington, D.C. 20008	Konstruktion	NORTHEAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS, TRANSACTIONS Bolbec Hall Newcastle upon Tyne 1, UK	NE Coast Instn. Engrs. Shipbdrs., Trans.
LUBRICATION ENGINEERING American Society of Lubrication Engineers 838 Busse Highway Park Ridge, IL 60068	Lubric. Engrg.	NUCLEAR ENGINEERING AND DESIGN North Holland Publishing Co. P.O. Box 3489 Amsterdam, The Netherlands	Nucl. Engrg. Des.
MACHINE DESIGN Penton Publishing Co. Penton Bldg. Cleveland, OH 44113	Mach. Des.	OIL AND GAS JOURNAL The Petroleum Publishing Co. 211 S. Cheyenne Tulsa, OK 74101	Oil Gas J.
MASCHINENBAUTECHNIK VEB Verlag Technik Oranienburger Str. 13/14 102 Berlin, E. Germany	Maschinen- bautechnik	PACKAGE ENGINEERING 5 S. Wabash Ave. Chicago, IL 60603	Package Engrg.
MECCANICA Pergamon Press, Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Meccanica	PLANT ENGINEERING 1301 S. Grove Avenue Barrington, IL 60010	Plant Engrg.
MECHANICAL ENGINEERING American Society of Mechanical Engineers 345 East 45th St. New York, NY 10017	Mech. Engrg.	POWER P.O. Box 521 Hightstown, NJ 08520	Power
MECHANICS RESEARCH AND COMMUNICATIONS Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mechanics Res. Comm.	POWER TRANSMISSION DESIGN Industrial Publishing Co. Division of Pittway Corp. 812 Huron Rd. Cleveland, OH 44113	Power Transm. Des.
MECHANISM AND MACHINE THEORY Pergamon Press Inc. Maxwell House, Fairview Park Elmsford, NY 10523	Mech. Mach. Theory	QUARTERLY JOURNAL OF MECHANICS AND APPLIED MATHEMATICS Wm. Dawson & Sons, Ltd. Cannon House Folkestone, Kent, UK	Quart. J. Mechanics Appl. Math.
MEMOIRES OF THE FACULTY OF ENGINEERING, KYOTO UNIVERSITY Kyoto University Kyoto, Japan	Mem. Fac. Engrs. Kyoto Univ.	REVUE ROUMAINE DES SCIENCES TECHNIQUES, SERIE DE MECANIQUE APPLIQUEE Editions De L'Academie De La Republique Socialiste de Roumanie 3 Bis Str., Gutenberg, Bucurest, Romania	Rev. Roumaine Sci. Tech., Mecanique Appl.
MTZ MOTORTECHNISCHE ZEITSCHRIFT Franskh'che Verlagshandlung Pfizenstrasse 6-7 7000 Stuttgart 1 W. Germany	MTZ Motor- tech. Z.	REVIEW OF SCIENTIFIC INSTRUMENTS American Institute of Physics 335 East 45th St. New York, NY 10017	Rev. Scientific Instr.
NAVAL ENGINEERS JOURNAL American Society of Naval Engineers, Inc. Suite 507, Continental Bldg. 1012 - 14th St., N.W. Washington, D.C. 20005	Naval Engr. J.	SAE PREPRINTS Society of Automotive Engineers Two Pennsylvania Plaza New York, NY 10001	SAE Prepr.
		SIAM JOURNAL ON APPLIED MATHEMATICS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Appl. Math.

PUBLICATION AND ADDRESS	ABBREVIATION	PUBLICATION AND ADDRESS	ABBREVIATION
SIAM JOURNAL ON NUMERICAL ANALYSIS Society for Industrial and Applied Mathematics 33 S. 17th St. Philadelphia, PA 19103	SIAM J. Numer. Anal.	VDI FORSCHUNGSSHEFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Forsch.
STROJNICKÝ ČASOPIS Red. Strojnickeno Časopisu ČSAV A SAV USTAV MECHANIKY STROJOV SAV Bratislavská-Patrónka, Dubrovská cesta, ČSSR Czechoslovakia	Strojnický Časopis	VEHICLE SYSTEMS DYNAMICS Swets and Zeitlinger N.V. 347 B. Herreweg Lisse, The Netherlands	Vehicle Syst. Dyn.
S/V, SOUND AND VIBRATION Acoustic Publications, Inc. 27101 E. Ovia Rd. Bay Village, OH 44140	S/V, Sound Vib.	VIBROTECHNIKA Kauno Polytechnikos Institutas 2 Donelaitio g-vė 17 23300 Kaunas Lithuanian SSR	Vibro- technika
TECHNISCHES MESSEN - ATM R. Oldenburg Verlag GmbH Rosenheimer Str. 145 8 München 80, W. Germany	Techn. Messen-ATM	WAVE MOTION North Holland Publishing Co. P.O. Box 211 1000 AE Amsterdam The Netherlands	Wave Motion
TEST 61 Monmouth Road Oakhurst, NJ 07755	Test	WEAR Elsevier Sequoia S.A. P.O. Box 851 1001 Lausanne 1, Switzerland	Wear
TRIBOLOGY INTERNATIONAL IPC Science and Technology Press Ltd. Westbury House P.O. Box 63, Bury Street Guildford, Surrey GU2 5BH, UK	Tribology Intl.	ZEITSCHRIFT FÜR ANGEWANDTE MATHEMATIK UND MECHANIK Akademie Verlag GmbH Liepäziger Str. 3-4 108 Berlin, Germany	Z. angew. Math. Mech.
TURBOMACHINERY INTERNATIONAL Turbomachinery Publications, Inc. 22 South Smith St. Norwalk, CT 06855	Turbomach. Intl.	ZEITSCHRIFT FÜR FLUGWISSENSCHAFTEN DFVLR D-3300 Braunschweig Flughafen, Postfach 3267 W. Germany	Z. Flugwiss.
VDI ZEITSCHRIFT Verein Deutscher Ingenieur GmbH Postfach 1139, Graf-Recke Str. 84 4 Düsseldorf 1, Germany	VDI Z.		

## SECONDARY PUBLICATIONS SCANNED

GOVERNMENT REPORTS ANNOUNCEMENTS & INDEX NTIS U.S. Dept. of Commerce Springfield, VA 22161	GRA	DISSERTATION ABSTRACTS INTERNATIONAL University Microfilms Ann Arbor, MI 48106	DA
SCIENTIFIC AND TECHNICAL AEROSPACE REPORTS Superintendent of Documents U.S. Government Printing Office Washington, D.C. 20402	STAR		

## ANNUAL PROCEEDINGS SCANNED

INSTITUTE OF ENVIRONMENTAL SCIENCES, ANNUAL PROCEEDINGS Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056	Inst. Environ. Sci., Proc.	THE SHOCK AND VIBRATION BULLETIN, UNITED STATES NAVAL RESEARCH LABORATORIES, ANNUAL PROCEEDINGS Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375	Shock Vib. Bull., U.S. Naval Res. Lab., Proc.
TURBOMACHINERY SYMPOSIUM Gas Turbine Labs Texas A&M University College Station, Texas	Turbomach. Symp.		

# CALENDAR

## FEBRUARY 1982

22-26 SAE Congress and Exposition [SAE] Detroit, MI  
(*SAE Hqs.*)

## MARCH 1982

29-Apr 1 Design Engineering Conference and Show [ASME]  
Chicago, IL (*ASME Hqs.*)

30-Apr 1 Machinery Vibration Monitoring and Analysis  
Meeting [Vibration Institute] Oak Brook, IL  
(*Ronald L. Eshleman, Director, Vibration Institute,  
101 W. 55th St., Suite 206, Clarendon Hills,  
IL 60514 - (312) 654-2254*)

## APRIL 1982

14-16 Fatigue Conference & Exposition [SAE] Dearborn, MI (*SAE Hqs.*)

18-22 Gas Turbine Conference and Products Show [ASME] London, England (*ASME Hqs.*)

20-22 Mechanical Failures Prevention Group 35th Symposium [National Bureau of Standards] Gaithersburg, MD (*Dr. James G. Early, National Bureau of Standards, Bldg. 223/Room A-113, Washington, DC 20234 - (301) 921-2976*)

20-23 Institute of Environmental Sciences' 28th Annual Technical Meeting [IES] Atlanta, GA (*IES, 940 E. Northwest Highway, Mt. Prospect, IL 60056 - (312) 255-1561*)

22-23 13th Annual Pittsburgh Conference on Modeling and Simulation [School of Engineering, Univ. of Pittsburgh] Pittsburgh, PA (*William G. Vogt or Martin H. Mickle, Modeling and Simulation Conf., 348 Benedum Engrg. Hall, Univ. of Pittsburgh, Pittsburgh, PA 15261*)

26-30 Acoustical Society of America, Spring Meeting [ASA] Chicago, IL (*ASA Hqs.*)

## MAY 1982

12-14 Pan American Congress on Productivity [SAE] Mexico City (*SAE Hqs.*)

24-26 Commuter Aircraft and Airline Operations Meeting [SAE] Savannah, GA (*SAE Hqs.*)

## JUNE 1982

7-11 Passenger Car Meeting [SAE] Dearborn, MI (*SAE Hqs.*)

## JULY 1982

13-15 'Environmental Engineering Today' Symposium and Exhibition [SEE] London, England (*SEE, Owles Hall, Buringford, Herefordshire, UK*)

19-21 12th Intersociety Conference on Environmental Systems [SAE] San Diego, CA (*SAE Hqs.*)

## AUGUST 1982

16-19 West Coast International Meeting [SAE] San Francisco, CA (*SAE Hqs.*)

## SEPTEMBER 1982

13-16 International Off-Highway Meeting & Exposition [SAE] Milwaukee, WI (*SAE Hqs.*)

## OCTOBER 1982

4-6 Convergence '82 [SAE] Dearborn, MI (*SAE Hqs.*)

4-7 Symposium on Advances and Trends in Structural and Solid Mechanics [George Washington Univ. and NASA Langley Res. Ctr.] Washington, DC (*Prof. Ahmed K. Noor, Mail Stop 246, GWU-NASA Langley Res. Ctr., Hampton, VA 23665 - (804) 827-2897*)

12-15 Stapp Car Crash Conference [SAE] Ann Arbor, MI (*SAE Hqs.*)

25-28 Aerospace Congress & Exposition [SAE] Anaheim, CA (*SAE Hqs.*)

## NOVEMBER 1982

8-12 Acoustical Society of America, Fall Meeting [ASA] Orlando, Florida (*ASA Hqs.*)

8-12 Truck Meeting & Exposition [SAE] Indianapolis, IN (*SAE Hqs.*)

14-19 American Society of Mechanical Engineers, Winter Annual Meeting [ASME] Phoenix, AZ (*ASME Hqs.*)

**CALENDAR ACRONYM DEFINITIONS AND ADDRESSES OF SOCIETY HEADQUARTERS**

<b>AFIPS:</b>	American Federation of Information Processing Societies 210 Summit Ave., Montvale, NJ 07645	<b>IEEE:</b>	Institute of Electrical and Electronics Engineers 345 E. 47th St. New York, NY 10017
<b>AGMA:</b>	American Gear Manufacturers Association 1330 Mass Ave., N.W. Washington, D.C.	<b>IES:</b>	Institute of Environmental Sciences 940 E. Northwest Highway Mt. Prospect, IL 60056
<b>AHS:</b>	American Helicopter Society 1325 18 St. N.W. Washington, D.C. 20036	<b>IFToMM:</b>	International Federation for Theory of Machines and Mechanisms U.S. Council for TMM c/o Univ. Mass., Dept. ME Amherst, MA 01002
<b>AIAA:</b>	American Institute of Aeronautics and Astronautics, 1290 Sixth Ave. New York, NY 10019	<b>INCE:</b>	Institute of Noise Control Engineering P.O. Box 3206, Arlington Branch Poughkeepsie, NY 12603
<b>AIChE:</b>	American Institute of Chemical Engineers 345 E. 47th St. New York, NY 10017	<b>ISA:</b>	Instrument Society of America 400 Stanwix St. Pittsburgh, PA 15222
<b>AREA:</b>	American Railway Engineering Association 59 E. Van Buren St. Chicago, IL 60605	<b>ONR:</b>	Office of Naval Research Code 40084, Dept. Navy Arlington, VA 22217
<b>ARPA:</b>	Advanced Research Projects Agency	<b>SAE:</b>	Society of Automotive Engineers 400 Commonwealth Drive Warrendale, PA 15096
<b>ASA:</b>	Acoustical Society of America 335 E. 45th St. New York, NY 10017	<b>SEE:</b>	Society of Environmental Engineers 6 Conduit St. London W1R 9TG, UK
<b>ASCE:</b>	American Society of Civil Engineers 345 E. 45th St. New York, NY 10017	<b>SESA:</b>	Society for Experimental Stress Analysis 21 Bridge Sq. Westport, CT 06880
<b>ASME:</b>	American Society of Mechanical Engineers 345 E. 45th St. New York, NY 10017	<b>SNAME:</b>	Society of Naval Architects and Marine Engineers 74 Trinity Pl. New York, NY 10006
<b>ASNT:</b>	American Society for Nondestructive Testing 914 Chicago Ave. Evanston, IL 60202	<b>SPE:</b>	Society of Petroleum Engineers 6200 N. Central Expressway Dallas, TX 75206
<b>ASQC:</b>	American Society for Quality Control 161 W. Wisconsin Ave. Milwaukee, WI 53203	<b>SVIC:</b>	Shock and Vibration Information Center Naval Research Lab., Code 5804 Washington, D.C. 20375
<b>ASTM:</b>	American Society for Testing and Materials 1916 Race St. Philadelphia, PA 19103	<b>URSI-USNC:</b>	International Union of Radio Science - U.S. National Committee c/o MIT Lincoln Lab. Lexington, MA 02173
<b>CCCAM:</b>	Chairman, c/o Dept. ME, Univ. Toronto, Toronto 5, Ontario, Canada		
<b>ICF:</b>	International Congress on Fracture Tohoku Univ. Sendai, Japan		

**PUBLICATIONS AVAILABLE FROM  
THE SHOCK AND VIBRATION INFORMATION CENTER  
CODE 5804, Naval Research Laboratory, Washington, D.C. 20375**

**PRICES**

**Effective - 1 September 1981**

	<u>U.S.</u>	<u>FOREIGN</u>
<b>SHOCK AND VIBRATION DIGEST</b>		
SVD-14 (Jan. - Dec. 1982)	\$140.00	\$175.00
<b>SHOCK AND VIBRATION BULLETINS</b>		
SVB-47	\$ 15.00	\$ 18.00
SVB-48	30.00	37.50
SVB-49	30.00	37.50
SVB-50	60.00	75.00
SVB-51	100.00	125.00
SVB-52	140.00	175.00
<b>SHOCK AND VIBRATION MONOGRAPHS</b>		
SVM-2, Theory and Practice of Cushion Design	\$ 10.00	\$ 12.50
SVM-4, Dynamics of Rotating Shafts	10.00	12.50
SVM-5, Principles and Techniques of Shock Data Analysis	5.00	6.25
SVM-6, Optimum Shock and Vibration Isolation	5.00	6.25
SVM-7, Influence of Damping in Vibration Isolation	15.00	18.75
SVM-8, Selection and Performance of Vibration Tests	10.00	12.50
SVM-9, Equivalence Techniques for Vibration Testing	10.00	12.50
SVM-10, Shock and Vibration Computer Programs	10.00	12.50
SVM-11, Calibration of Shock and Vibration Measuring Transducers	25.00	31.25
SVM-12, Balancing of Rigid and Flexible Rotors	50.00	62.50

**SPECIAL PUBLICATIONS**

An International Survey of Shock and Vibration Technology	\$ 30.00	\$ 37.50
The Environmental Qualification Specification as a Technical Management Tool	12.00	15.00

To order any publication, simply check the line corresponding to that publication that appears below, and mail the postage free card. You will be invoiced at the time of shipment.

Please send the following publication(s) to me:

Name \_\_\_\_\_

- SVD-14       SVM-5
- SVB-47       SVM-6
- SVB-48       SVM-7
- SVB-49       SVM-8
- SVB-50       SVM-9
- SVB-51       SVM-10
- SVB-52       SVM-11
- SVM-2       SVM-12
- SVM-4
- International Survey
- Qual. Spec. Report

Address \_\_\_\_\_

Mail invoice to: (if other than above)  
 \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

**DEPARTMENT OF THE NAVY**

**NAVAL RESEARCH LABORATORY, CODE 5804  
SHOCK AND VIBRATION INFORMATION CENTER  
Washington, D.C. 20375**

**OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300**

**POSTAGE AND FEES PAID  
DEPARTMENT OF THE NAVY  
DOD-316**



**The Shock and Vibration Information Center  
Naval Research Laboratory  
Code 5804  
Washington D.C. 20375**

## PUBLICATION POLICY

Unsolicited articles are accepted for publication in the Shock and Vibration Digest. Feature articles should be tutorials and/or reviews of areas of interest to shock and vibration engineers. Literature review articles should provide a subjective critique/summary of papers, patents, proceedings, and reports of a pertinent topic in the shock and vibration field. A literature review should stress important recent technology. Only pertinent literature should be cited. Illustrations are encouraged. Detailed mathematical derivations are discouraged; rather, simple formulas representing results should be used. When complex formulas cannot be avoided, a functional form should be used so that readers will understand the interaction between parameters and variables.

Manuscripts must be typed (double-spaced) and figures attached. It is strongly recommended that line figures be rendered in ink or heavy pencil and neatly labeled. Photographs must be unscreened glossy black and white prints. The format for references shown in DIGEST articles is to be followed.

Manuscripts must begin with a brief abstract, or summary. Only material referred to in the text should be included in the list of References at the end of the article. References should be cited in text by consecutive numbers in brackets, as in the example below.

Unfortunately, such information is often unreliable, particularly statistical data pertinent to a reliability assessment, as has been previously noted [1].

Critical and certain related excitations were first applied to the problem of assessing system reliability almost a decade ago [2]. Since then, the variations that have been developed and the practical applications that have been explored [3-7] indicate that . . .

The format and style for the list of References at the end of the article are as follows:

- each citation number as it appears in text (not in alphabetical order)
- last name of author/editor followed by initials or first name
- titles of articles within quotations, titles of books underlined

- abbreviated title of journal in which article was published (see Periodicals Scanned list in January, June, and December issues)
- volume, number or issue, and pages for journals; publisher for books
- year of publication in parentheses

A sample reference list is given below.

1. Pletzer, M.F., "Trensonic Blade Flutter - A Survey," *Shock Vib. Dig.*, 7 (7), pp 97-106 (July 1975).
2. Bisplinghoff, R.L., Ashley, H., and Halfman, R.L., Aeroelasticity, Addison-Wesley (1955).
3. Jones, W.P., (Ed.), "Manual on Aeroelasticity," Part II, Aerodynamic Aspects, Advisory Group Aeronaut. Res. Devel. (1962).
4. Lin, C.C., Raissner, E., and Tsien, H., "On Two-Dimensional Nonsteady Motion of a Slender Body in a Compressible Fluid," *J. Math. Phys.*, 27 (3), pp 220-231 (1948).
5. Lendahl, M., Unsteady Transonic Flow, Pergamon Press (1961).
6. Miles, J.W., "The Compressible Flow Past an Oscillating Airfoil in a Wind Tunnel," *J. Aeronaut. Sci.*, 23 (7), pp 671-678 (1956).
7. Lane, F., "Supersonic Flow Past an Oscillating Cascade with Supersonic Leading Edge Locus," *J. Aeronaut. Sci.*, 24 (1), pp 65-66 (1957).

Articles for the DIGEST will be reviewed for technical content and edited for style and format. Before an article is submitted, the topic area should be cleared with the editors of the DIGEST. Literature review topics are assigned on a first come basis. Topics should be narrow and well-defined. Articles should be 1500 to 2500 words in length. For additional information on topics and editorial policies, please contact:

Milda Z. Tarnulionis

Research Editor

Vibration Institute

101 West 55th Street, Suite 206

Clarendon Hills, Illinois 60514

**DEPARTMENT OF THE NAVY**

NAVAL RESEARCH LABORATORY, CODE 5804  
SHOCK AND VIBRATION INFORMATION CENTER  
Washington, D.C. 20375

POSTAGE AND FEES PAID  
DEPARTMENT OF THE NAVY  
DOD-316



OFFICIAL BUSINESS  
PENALTY FOR PRIVATE USE, \$300

THE SHOCK AND VIBRATION DIGEST

Volume 13, No. 12

December 1981

EDITORIAL

## **SVIC Notes**

## ARTICLES AND REVIEWS

### **3 Feature Article - FINITE-ELEMENT MODELING OF LAYERED, ANISOTROPIC COMPOSITE PLATES AND SHELLS: A REVIEW OF RECENT RESEARCH**

### 13 Literature Review

15 VORTEX SHEDDING FROM CYLINDERS AND THE RESULTING UNSTEADY FORCES AND FLOW PHENOMENA. PART II

S.T. Fleischmann and D.W. Sallet

25 Annual Article Index  
27 Book Reviews  
30 Book Reviews: 1981

## CURRENT NEWS

**33 Short Courses**  
**35 News Briefs**  
**36 Information Resources**

## ABSTRACTS FROM THE CURRENT LITERATURE

39	Abstract Categories
40	Abstract Contents
41	Abstracts: 81-2505 to 81-2691
87	Annual Author Index
113	Annual Subject Index
169	Technical Notes
170	Periodicals Scanned

## CALENDAR